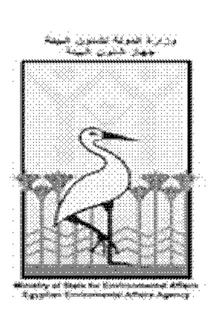
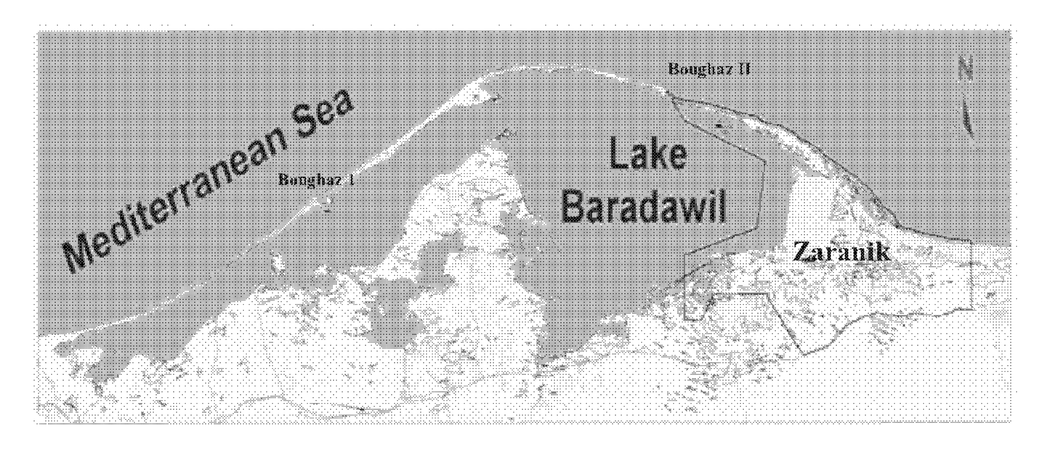
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MINISTRY STATE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF NATURE PROTECTION
MedWetCoast Project



Lake Bardawil

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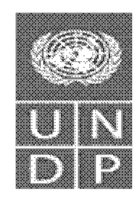
Zaranik Protected Area

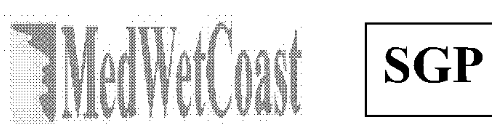


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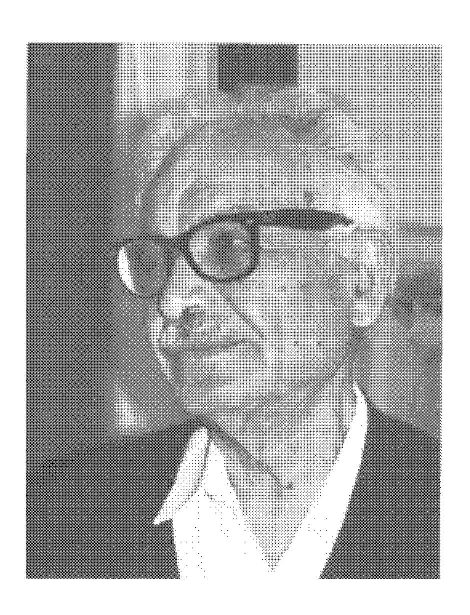
LANDSAT SATELLITE IMAGE
OF THE ARAB REPUBLIC OF EGYPT
FROM 950 Km ALTITUDE

صورة فضائية لجمهورية مصر العربية
من القمر الصناعي لاندسات
من ارتفاع ٩٥٠ كيلو متر

SINAI

GREAT SAND SEA

SUDAN



A festschrift for Prof. M. Kassas on the occasion of his 85th birthday, but for his help and support this series of NBU books, would never have appeared.

PREFACE

Lake Bardawil is a prominent landform feature of North Sinai, a saltwater wetland that retains most of its pristine ecology. It sits along one of the principal flyways of migratory birds in their seasonal voyages between the Euro-Asian palearctics and the African tropics. It stretches along the northern side of the transcontinental road that witnessed throughout millennia of human history: armies marching eastward from Egypt to Western Asia or westward from Asia to invade Egypt, the holy family fleeing from Roman harassment in Palestine to their refuge in Egypt, and endless journeys of trade, pilgrimage, etc. Lake Bardawil, its isles and its outskirts bear relics of all this history, and have been the subject of innumerable surveys and studies in diverse disciplines and for diverse purposes.

The declaration of the eastern lobe of Lake Bardawil, the Zaranik, as a protected area (under Law 102, 1983) by Prime-minister's Decree in 1985, amended in 1996, initiated several studies and surveys of its biodiversity. These surveys were further intensified under the MedwetCoast-Egypt project (2000-2006) in the preparatory phase (diagnostic studies) towards setting a management plan for the protected area and its surroundings (achieved in 2002). The two principal authors of this volume and their associate contributors were involved in these recent studies. This made them best qualified to collate and digest the rich volume of data on the Lake.

A principal purpose of this volume and of the two previous volumes on Lake Nasser (2000) and Lake Burullus (2005), publications of the National Biodiversity Unit, Nos. 11 and 13, is to salvage and document the wealth of information reported in hundreds of theses, papers, reports, etc. The goal is to avoid the sad end of several series of research and experimental studies that were carried out during the 20th Century and were not fully recorded and their lessons-learned were lost, e.g., field agriculture experimental station of Borg-el-Arab (1921-1977) and the sand-dune fixation experiment at Boseili (1919-1959), etc. This volume, and others in this series, aim at saving these information and providing base-line data for future programmes of research, monitoring and development of natural resources.

The Bardawil area is a part of the Mediterranean coastal lands of Egypt. Its prevalent climate belongs to the dry lands of the southern Mediterranean (low winter rainfall: less than 200 mm/year). For the landform set-up, it is a coastal lagoon with access to the sea through a set (three) natural and man-made inlets: all need maintenance to keep them functioning. The lagoon is hypersaline, seawater prevails, it receives little seepage of underground fresh water and

limited rainfall and no agricultural drainage (compared to other Delta coastal lakes that receive considerable volumes of semi-fresh water debouched by agricultural drains). The hydrological balance of all these lakes, including Lake Bardawil, is a key ecological factor. Chapter 1 of this volume, a multidisciplinary assessment, sets the scene of the ecological background of Lake Bardawil and its outskirts. Quantitative analyses of water balance of coastal wetlands were among the pioneering studies of this series.

Subsequent chapters are a series of thematic studies, each surveying the ecological significance of one feature (a process) or one taxon of the biota recorded in the area. Here data are collected and analysed to uncover their ecological, biogeographical and historical significance. Two aspects of ecology are underlined: biodiversity richness and its significance, and impacts of development (use of natural recourses at present and envisaged in future development programmes). Two aspects of biogeography are noted: the palearctic-tropical bird voyages and the Red Sea- Mediterranean biotic exchange via the Suez Canal.

Chapter 12 (Birds) addresses a particularly significant group of rich and diverse biota of the regions: c. 242 species including numerous migratory species. Because the voyage of the latter group between the temperate north and the warm south, they are of international concern. Their likely role in carrying pathogenic elements was monitored during episodes of avian flu endemic. Lake Bardawil is a site that is valued and hence qualified to the Ramsar list of wetlands of international importance.

To these ecological surveys, chapter 14 describes socio-economic features prevalent in the area. These include the processes operative within the communities (socio-cultural) and the relationships of societies and their life-support systems of natural resources in terrestrial (farming, grazing, etc.) and aquatic (fishing, etc.) ecosystems. The understanding of these processes provides bases for assessing the community abilities to contribute to, and participate in, the ecologically sound management of the area.

The final chapter outlines elements of the management plan set for the Zaranik Protected Area (PA). It also implies consideration of prospects of expanding the PA to cover the whole area of Lake Bardawil and keeping Zaranik as its core. Because Lake Bardawil and its outskirts provide the life-support systems of associated human communities (fishermen, farmers, graziers, bird-hunters, etc.) its management needs to be on bases of environment-integrity and not just protection. Lake Bardawil is likely to be environmentally impacted by major development schemes (land reclamation, industry, roads, summer resorts, etc.) This will require establishment of an environment monitoring (and assessment) system.

This is an encyclopedic compendium of information on a wetland and its national and international importance. The two authors well deserve praise together with the many Egyptian and non-Egyptian scholars who contributed to the rich pool of ecological knowledge summed in this volume. The Egyptian Environmental Affairs Agency (EEAA) through its National Biodiversity Unit (NBV) made the compilation and publication of this volume possible, and deserves special acclaim. The Ministry of State for Environmental Affairs, the MedWet regional programme (supported by GEF and UNDP) provided financial support to programmes of research and surveys of the MedWetCoast- Egypt project that form the main source of this welcome volume.

M. Kassas
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November 2006

FOREWORD



I have special pleasure to introduce this comprehensive volume on Lake Bardawil and its surrounding wetlands. This publication is a part of our national endeavour in the fields of conservation and sustainable management of Egyptian wetlands. Lake Bardawil, by virtue of its position in North Sinai and on one of the principal flyway routes of international bird travel between the Palaearctics and Tropics, is a wetland formation of significant importance on the national and international scales. It justifiably deserves its inclusion in the Ramsar list of wetlands of world importance.

The North Sinai Agricultural Development Project (NSADP), as proposed and implemented by the Egyptian Government, was started in 1992 to reclaim and irrigate ca. 400, 000 Feddan with fresh water from the Nile mixed with reused water from El-Sirw and Bahr Hadous Drains, via El-Salam Canal, which crosses Suez Canal through a siphon of about 1.3 km long. No doubt, this project will initiate major changes upon the natural ecosystems in this region, where Lake Bardawil and its surrounding wetlands are prominent geomorphological units. For example, a major part of the domestic, industrial and agricultural run-off water of the proposed project would be drained into Lake Bardawil, an oligotrophic hypersaline desert lake of international conservation importance.

Extensive surveys and research studies on this lake, its habitats, biota, history and socioeconomic activities, among others, have been carried out, some were published and others remained unpublished reports. A principal purpose of this publication is to digest the rich volume of information contained in the wealth of disparate studies, assess the ecological changes and their impacts on biodiversity and on people.

The authors carried out their assignment with high-level of proficiency. Efforts invested in this endeavour are evident and commendable, and it is my pleasure to record my appreciation for a welcome volume that is informative and that provides guidance to steps in schemes of sustainable development of natural patrimony and conservation of biodiversity. The book will also provide useful reference for students of limnology and hydrobiology of Lake Bardawil in particular and the northern lakes of Egypt in general.

This is a particularly welcome contribution to the series of publications produced by the National Biodiversity Unit (NBU).

November 2006

Maged George Elias
Minister of state for the Environment

Credit

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Information in this book is based on the literature referenced in each chapter and the scientific reports of MedWetCoast Project No. EGY/97/G33/A/1G/99

Abdel-Dayem, M. S.…………………………….	Entomology
Basyouni, Mohamed.…………………………...	Mammalogy
Bayoumi, Gehan.……………………………….	Geomorphology
El-Gazzar, Adel.………………………………...	Management Plan
El-Hawagry, M. S.……………………………...	Entomology
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Fadl, H. H.……………………………………….	Entomology
Fathi, Amr.……………………………………..	Sociology
Hamied, Waheed. S.…………………………….	Ornithology
Hennawy, Hesham K.………………………….	Arachnida
Ibrahim, A. A.………………………………….	Herpetology
Khedr, Abdel Hameed.……………………….	Phytoecology
Rihan, Ibrahim.………………………………...	Socio-economics
Shaker, Fares A.………………………………...	Economics
Shennawy, Ibrahim.…………………………….	Hydrology
Tharwat, Mahmoud E.………………………...	Ornithology

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Last but not least, we warmly thank **our wives, sons and daughters** for their continuous encouragement and patience allover the period of preparing this book.

The authors

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INTRODUCTION

Wetlands are of ecological importance due to their hydrologic attributes and their being ecotones between terrestrial and aquatic ecosystems. They are sometimes described as the kidney of the landscape because they function as downstream receivers of water and waste from both natural and human sources. They have been subject to transformation to dry lands for agriculture schemes and human settlements, among others. River control schemes have often caused the loss, or area reduction of wetlands. The attributes of wetlands include high productivity, sources, sinks and transformers of numerous chemical, biological and genetic materials, and valuable habitats for fisheries, wildlife and birds. Conservation associations and bodies worldwide noted and described the alarming changes in these important habitats. This led to the Convention on Wetlands known as Ramsar Convention in 1971.

The definition of U.S. National Academy of Science for a wetland is "an ecosystem that depends on constant or recurrent shallow inundation or saturation at or near the surface of substrate". Its minimum essential characteristics are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical and biological feature reflective of recurrent sustained inundation or saturation: the common diagnostic features hydric soils and hydrophytic vegetation. These features will be present except certain specific physiochemical, biotic or anthropogenic factors have removed them or prevented their development". The international definition of Ramsar Convention is: "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed 6 meters".

Lake Bardawil is one of the five northern lakes in Egypt. It is bordered from the north by a convex sand barrier that separates it from the Sinai Mediterranean coast and from the south by the sand dune belt, which extends inland to the region of fold and anticlinal hills. The extreme eastern part of this lake (i.e. Zaranik Lagoon) is a Ramsar site and has been declared as a natural protectorate in 1985. This lake has an elliptical shape representing a major morphological feature along North Sinai coast. Its area is about 164,000 Feddan and extends for a distance of 80 km along N-S axis. Its maximum width is 20 km and maximum depth is 3 m. The main water body of this lake lies towards the east with an area of 58,000 Feddan of which Zaranik Lagoon occupies about 10,000 Feddan. Several geomorphic and landform features produced by marine and aeolian processes characterize Lake Bardawil: shore landforms represented by foreshore slope, backshore flats, playas, sand sheets and dunes; lagoonal

landforms represented by the Bardawil lagoon, islands, inlets, barrier sand flats, and sabkhas; and aeolian landforms represented by the sand accumulation and sand dunes. Considering these landforms and the biota that inhabit them, 6 major habitat types are clearly distinguished in this lake: salt marshes, saline sand flats, sand hillocks, stabilized sand dunes, inter-dunes depressions, mobile sand dunes and mud flats. Wintering and migrant birds are strongly dependent on these habitats and their vegetation for foraging, refuge and breeding.

Lake Bardawil had been the subject of many studies during the last 20 years (1985–2005). Many theses, reports and papers had been published covering the geomorphology, morphometry, sedimentology, hydrology and water quality, macrophytes, microphytes and phytoplankton, zooplankton and zoobenthos, fishes and fisheries, avifauna and others. The diagnostic studies of the Project "Conservation of Wetland and Coastal Ecosystems in the Mediterranean Region (MedWetCoast)", in 2000 and afterwards, have enriched and updated the available information and data about the biotic and abiotic components of the ecosystem of this lake. Unfortunately, most of these scientific materials are either of limited distribution, unavailable or not accessible to many of the concerned personnel. This encouraged the authors to collect, organize and analyze these scattered information and data, and to incorporate their own recent studies, into one volume deals with the physical features and biotic components as well as the socio-economy of the wetland of Lake Bardawil.

This treatise includes an introduction and 15 chapters in addition to collective English and Arabic summaries. Each chapter is ended by a summary and list of references, and in many chapters by plates of characteristic physical and biotic features. **The first chapter** includes the general properties of the Bardawil Wetland such as the location, geology, geomorphology, climatology, habitat types, hydrology and environmental impacts upon the habitats and their biota. Geomorphology presents information about the shape, dimension and morphometry of the lake, geomorphological features produced by the marine and aeolian processes in the lake. The climatic data of the nearest two meteorological stations to Bardawil Wetland were analyzed. The major habitat types were described as well as the hydrology of the lake including the budget of water balance. At the end of this chapter, the environmental impacts upon the habitats and biodiversity in North Sinai, including Lake Bardawil, were assessed.

The spatial and temporal variations of twenty three water properties were analyzed in **chapter 2**. These properties are temperature, total dissolved salts, electric conductivity, oxygen properties (dissolved oxygen, chemical and biological oxygen demands), major anions (bicarbonate, chloride and sulphate), major cations (calcium, magnesium, sodium and potassium), dissolved salts (phosphate, ammonia, nitrate, nitrite and silicate) and heavy metals (copper, iron, cadmium, lead and zinc). In **chapter 3,** the spatial and temporal variations

of thirteen sediment properties were analyzed (texture, pH, organic matter, carbonate, phosphate, ammonia, nitrate, nitrite, iron, copper, zinc, lead and manganese).

The flora and vegetation of the lake proper, its islets as well as the sand bar that separates between the lake and the Mediterranean Sea were the subject of **chapter 4**. A checklist of the recorded species and their distribution among habitats are presented. The flora was analyzed in terms of life form, species diversity, phyto-geography and abundance. In addition, an emphasis on the endemic, rare and noteworthy species was done. The environmental and economic importance of the recorded species were assessed (in terms of grazing, fuel, medicinal, human food, timber and other uses). In **chapter 5**, the phytoplankton and epiphytic algae were analyzed in terms of species diversity and primary production of the three major algal divisions (Bacillariophyta, Chlorophyta and Cyanophyta). The epiphytic algal species on the common submerged sea grasses *Ruppia cirrhosa* and *Cymodocea nodosa* were also listed.

Although the studies on the aquatic microorganisms in Lake Bardawil are too limited, two groups "bacteria and actinomycetes" were described in **chapter 6** based on some recent publications. This chapter includes background; microbial count, biomass, activity and identification in the water and sediments. Zooplankton and zoobenthos were the subject of **chapters 7 and 8**, which evaluate the present status of the zooplankton and benthos biota (common, rare, disappeared and endemic species, as well as the new records).

Chapter 9 includes valuable information about the Bardawil fishes and fisheries. This includes the present status of fish species in terms of common, rare, very rare and disappeared species. The change in fish production from 1925 up to 2005 is also included. The fisheries were reviewed in terms of the biology of some common fishes, fishing gears and techniques, as well as fishing effort analysis. At the end, the main threats to fisheries of Lake Bardawil were diagnosed and recommendations for fisheries management were reported.

Chapter 10 includes detailed information about the Arachnida and insects of Bardawil Wetland. It includes species diversity, status of each species, its density and preferable habitats. **Chapter 11** deals with the amphibian and reptilian fauna, it contains systematic list for the recorded species taking into account the systematic position, common name, local and world distribution, preferable habitat, ecology and status of each species.

Chapter 12 includes the habitat types supporting important water birds in Lake Bardawil, breeding birds, and bird surveys. A checklist of the birds recorded during several bird surveys was presented, in addition to tables that include the status, abundance, national and world distribution of the recorded bird species. An emphasis was done on economic importance of bird species such as waterfowl hunting and capturing of the birds of prey. This chapter includes also some useful management practices that are needed to apply in

Bardawil Wetland for conserving such important biotic group. This chapter was ended by some information about the role of the migratory birds in the transmission of diseases. **Chapter 13** includes a list of the recorded mammalian fauna with focusing on the acceptable Latin names, common names, observation localities in Bardawil, national and world distributions, brief morphological descriptions, comparisons with the nearest species, types of habitat and ecology, with remarks from the previous literature.

Chapter 14 deals with the socio-economic development. It includes some information about the history and importance of Lake Bardawil, environmental setting, demographic development, economic activities such as agriculture, fishing, pasturing, tourism and bird hunting. This chapter includes also the results of a recent survey about education status, characteristics of local population and fishing activities.

The management plan for Zaranik Protectorate Area was the subject of **chapter 15**. The document of this plan was prepared by the MedWetCoast Project; includes five main parts: background, site description, evaluation and objectives, implementation and plan of action. As the first two parts (background and site description) are presented in more details in the previous chapters of the present book (1-14); chapter 15 deals only with the evaluation and objectives (first evaluation, ideal objectives for the site, constraints or modifiers, second evaluation and operational objectives), implementation (management strategies, zoning and prescriptions) and plan of action (management action plan, programs and objects).

As the authors are aware, the present book is an attempt to collect, organize and analyze available data and information about the wetland of Lake Bardawil, in a manner that may help the decision markers, conservationists, economic and environmental planners who are responsible for development and management, researchers, and even the students of biology and agriculture. It is hoped that the executive Arabic summary at the end of the book will offer scientific information to a broad sector of the Egyptians and others interested in this wetland.

The authors

Chapter 1
General Characteristics

1.1 LOCATION AND GENERAL DESCRIPTION

Northern Sinai, including Lake Bardawil, occupies about 8000 km^2, or 13% of the area of Sinai Peninsula. Lake Bardawil is mainly a flat low lying plain, bordered from the north by Sinai Mediterranean coast, from the south by a sand dune belt which extends inland to the region of fold and anticlinal hills, from the west by the Tineh Sabkha flat constituting eastern margin of the Nile Delta plain and from the east by Arish-Rafah sector. Its elliptical shape represents a major morphological feature in north Sinai coast (Fig. 1.1). This lagoon has an area about 164,000 Feddan (c. 685 km^2), extends for a distance of about 80 km, with a maximum width of about 20 km and a maximum depth of about 3 m. It is separated from the Mediterranean by a long convex sand bar; the main water body of the lagoon lies towards the east occupying a section along the coast of about 30 km long ending with Zaranik pond in the east (has an area of about 58,000 Feddan, of which Zaranik pond occupies about 10,000 Feddan). The latter is now exploited for salt production (it is called locally Malahat Sebikah). The western part of the lagoon extends as a long narrow arm of about 50 km length (it has an area of about 106,000 Feddan).

Sea water enters the lagoon at present through three inlets: two artificial tidal inlets (270 and 300 m wide and 4-7 m deep), they are maintained open by periodic dredging, and a natural eastern inlet of Zaranik which is now occasionally closed by silting. Fish production of Bardawil Lagoon depends on the water exchange between the lagoon and sea, which regulates lagoon salinity. Joined to Bardawil Lagoon, are a number of bays (e.g. El-Telul and Misfiq) and a few restricted shallow water ponds (e.g. El-Rowaq and El-Marqab to the south) in which water depth is only a few centimeters). In the southern areas of the lagoon, extensive salt pans-sabkha complex occur mostly interrupted by a series of sand dunes (ridges) running mostly parallel to the coast and extending southwards. Thus sabkhas of Bardawil may be coastal flat sabkhas fringing the lagoon particularly at the extreme eastern margins or dunal sabkhas south the lagoon (Shaheen 1998).

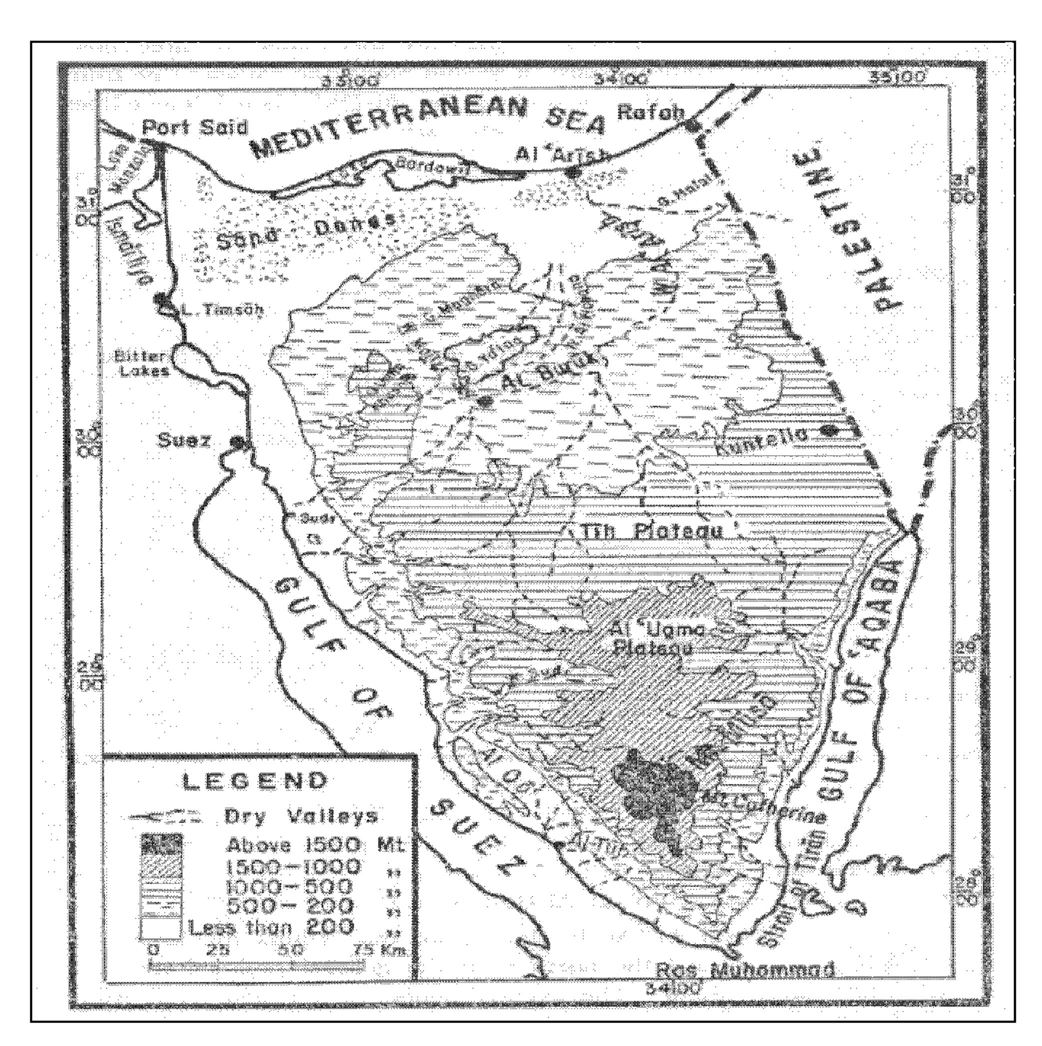


Fig. 1.1. **Relief Map of the Sinai Peninsula (Abu El-Izz 1971)**

Playas or small oases of silty soil are abundant scattered to the west and south of Bardawil Lagoon. These are developed where low sand dunes and sheets are deflated by wind down to new the groundwater level (e.g. Rabaa basin). In these playas fresh to brackish water provides for agricultural activities or natural vegetation.

Bardawil Lagoon is reached through the main asphaltic road from El-Kantra East to El-Arish. A group of side tracks from the main road that reach the lagoon are available. The nearest track at Misfiq is less than 1 km long, followed to the east by about 2 km long track to Tellul. Other side ways on the west at Arif El-Rabia and on the east at Zaranik protectorate are available.

El-Salam irrigation canal is a newly constructed canal running south the asphaltic road, but intersecting it only at Balouza. The canal is about 175 km long made to carry about 4.4 billion m^3 yr^{-1} of mixed water from the River Nile branch of Damietta and the drainage water now flowing to Lake Manzala for agricultural and settlement projects west and east the northern part of Suez Canal. The eastern part of El-Salam Canal running across north Sinai is called El-Sheikh Gaber Canal (Fig. 1.2).

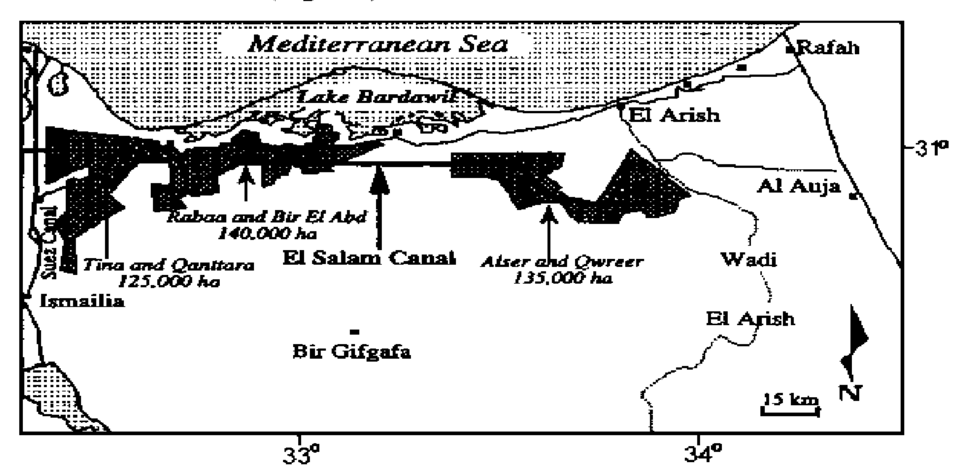


Fig. 1.2. **El-Salam canal and areas designated for reclamation and cultivation (shaded area)**

1.2 GEOLOGY

The bar separating the lake from the sea is arc-shaped, 300-1000 m wide. Its highest point is El-Kals (Mount Cassius), a 60 m high dune located about midway. The western part of the bar is an extension of a dune-covered higher ground which starts at Qantara on the Suez Canal (Pisanty 1980). This ridge is part of the Pelusium Line, a compressional zone dividing the thin Mediterranean crust on the east from the oceanic-type crust on the west. However, there is little evidence that the lake was the estuary of the Pelusiac branch of the Nile. Pelusiac branch debouched at a site situated to the west of the above mentioned ridge (Neev *et al.* 1976), but undoubtedly the Nile supplied the quantities of sand that formed of the bar separating the depression from the sea.

A geological description of the lagoon has been presented by Pisanty (1981). Sediment types distribution at a benthic depth of 0-20 cm indicates that the bottom of the lagoon is sandy on the periphery, clayey sand covers most of its area, and silty clay is found in its deepest parts (Fig. 1.3).

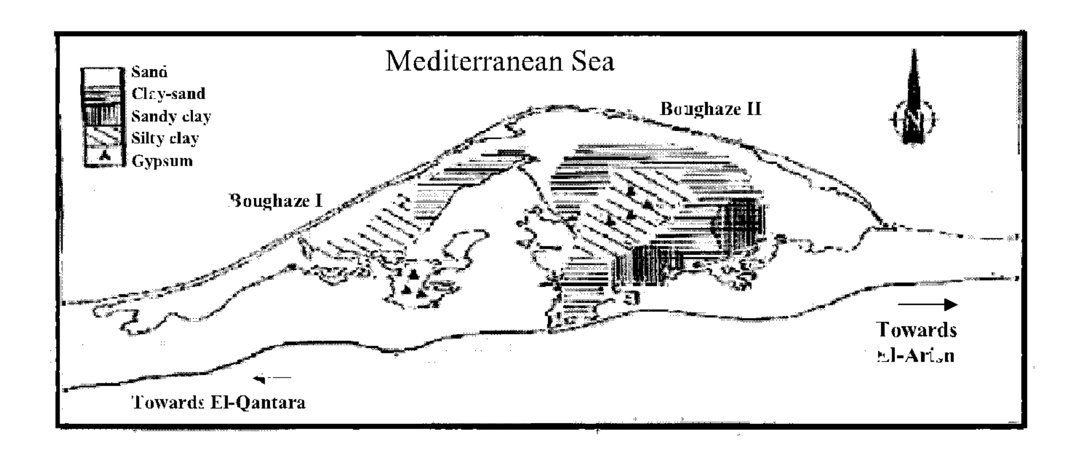


Fig. 1.3. **Sediment types distributed at a benthic depth of 0 – 20 cm (Abdel-Malek & Khalil 1994).**

1.3 GEOMORPHOLOGICAL UNITS

North Sinai consists of a wide plain sloping gradually northward. It is bordered by the region of folds in the south and the Mediterranean coast in the north. It extends to the Suez Canal in the west and narrows in the east due to the presence of Gabal Al-Maghara. Sand dunes are found in all parts of this wide plain with elevations up to 100 m; it seems that the accumulations of sand have buried the original geological structures. Geophysical studies have shown that those structures are similar to great folds with the same axes as domes in north central Sinai. Eolian deposition has thus played a great role in this region, forming dunes parallel to the northwesterly winds. The dunes near Gabal Al-Maghara extend from southwest to northeast, perhaps because of the influence of the mountain. The dunes in western Sinai are scattered in dune colonies (Abu El-Izz 1971).

Sand dunes have the ability to absorb rain water; thus the lowlands between the dunes are a permanent source of water that can be tapped by digging shallow wells. The wells of Sinai are distributed in three lines: 1- along the Mediterranean coast, 2- along the railway line from Al-Qantara to Rafah, and 3- along the Al-Qa Plain. These lines are related to the deposits of the Quaternary. Generally speaking, it can be said that the water of the sand dunes in northern Sinai improves as we move eastward away from the salty bogs. The best quality and quantity of water occur in the delta of Wadi El-Arish. The inhabitants of the Sinai Mediterranean coast collect the winter rains in old reservoirs hollowed in rocks (i.e. cisterns). The wells and springs in northern Sinai are closely related to the amount of rainfall along the northern coast; their water supply varies accordingly. The depth of the wells can be as little as three meters, or as much as sixty.

The existence of Lake Bardawil depends upon its connective with the Mediterranean. The low sand bar which separates the lake from sea is often covered by sea water. Lake El-Zaranik is joined to the sea by a narrow inlet; thus its water is constantly being replenished. In 1955, two inlets (i.e. Boughaze) were dug to connect the lake with the Mediterranean, one at the western end and the other at the eastern end of the lake. Each canal is one kilometer long and 150 m. wide. Lake Bardawil is the most saline of the northern Egyptian lakes, for it is connected only with the sea. Salinity increases with distance from the inlet canals.

One of the geomorphological questions concerning the formation of the northern sand bar of Sinai is whether it was formed by the deposits of the Nile which have been drifted by the eastward sea current or whether it was formed from the deposits of Wadi El-Arish (or whether both sources participated in its formation). In answering this question, let us point out the following (Abu El-Izz 1971): 1- it is clear that the Mediterranean coast of Sinai is a region of deposition; 2- Wadi El-Arish has contributed to the building of the coastal bar by the deposits which it brings at the time of floods, furthermore when the wadi flowed at a higher elevation and had a greater volume of water, it carried greater amounts of silt; and 3- Nile deposits brought by the pelusiac branch and drifted by the sea current toward the east constitute a source of deposits for the coastal bar.

Sinai coast is currently a precariously balanced coast. After the completion of the Aswan high Dam, Nile silt has ceased to reach the Mediterranean. Consequently the advance of the Sinai coast will decrease, but it will nonetheless continue because of the deposition by Wadi El-Arish. Bardawil Lagoon is elliptical in shape and occupies about half of the northern Sinai coast with significant convex barrier and different bottom configuration. It is possible that the curving of the northern coast of Sinai in the vicinity of Lake Bardawil (i.e. convex shape) resulted from the convergence of the prevalent eastward-moving of sea current with the current of Wadi El-Arish (Abu El-Ezz 1971). This convergence cuts down the speed of both currents and as a result, the load being transported by each water source is deposited at the location of their convergence.

The lagoonal area in general has relatively low relief and bounded from the north by the beach sand bar and from the south by sabkhas, extensive playas, sand sheets and sand dune fields reaching up to 40 m above sea level. Most of these playas and sand sheets are adjacent to the lagoon especially its western arm. Occasionally, aeolian sand encroachs upon parts of the main road and low lying interdunal depressions with palm groves. East of Bardawil Lagoon the coast extends almost east-west then it curves to the north east reaching the city of Rafah on the eastern Egyptian border. In general, the beach is sandy and rich in pelecypods shells.

Lagoon connection with the Mediterranean sea is maintained at present through two man-made inlets or "Boughaze" i.e. inlet 1 and inlet 2. The lagoon embraces small islands such as El-Romaia, El-Kals, El-Mahasnah and El-Watawite. On the other hand, the long lagoon western arm is connected with two water bodies named El-Rowaq and El-Marqab in the south through a narrow strait. Malahat Sebikah is a large pond to the east.

The curved barrier of the Bardawil Lagoon is a significant feature. It has a low relief, and is composed of Quaternary loose sands. These sands vary in colour from white to yellow or dark black due to the presence of heavy black minerals concentrated along the barrier. During high tides and winter storms, sea water may overcross the barrier, pass through inlets and dilute water salinity of the lagoon. Flat veneers of sabkhas surround the lagoon especially southwards. These occur in different elongated to circular patches with salt encrustation at their centers. Occasionally, they are separated by old ridges or dunes. The largest sabkhas in the studied area are El-Kofri and Hawash in the east and sabkhat El- Haswa in the west, with several small salt pans (mallahat). The salt occurring as white patches of surficial crusts is sometimes collected by the natives. Groves of olive and palm trees are widely scattered in the area particularly in interdunal depressions where fresh to brackish water is stored.

Shaheen (1998) described several geomorphic and landform features produced by marine and aeolian processes in Bardawil Lagoon. These include: shore landforms represented by (foreshore slope, backshore flats, playas, sand sheets and dunes). Lagoonal landforms are represented by the Bardawil Lagoon, islands, inlets, barrier sand flats, and sabkhas. Aeolian landforms are represented by the sand accumulation and sand dunes.

1.3.1 Shore Landforms

1.3.1.1 Beach (foreshore-backshore zones)

In the area of Bardawil Lagoon and its surroundings, the shore is about 80 km long. It consists of a convex segment with two concave segments on both sides, possibly controlled by NE faults (Pelusium System) and NW fault (Bardawil System). The change in direction of this shore line affects to a large extend the sediment borne by the W-E long shore sea currents and consequently process of deposition and erosion of the shore and its beach development. Therefore, the beach north the lagoon has a gentle slope and is rather thin (about 500 m width) and gets broader west and east of the lagoon. The foreshore zone is generally sandy of low elevation but getting higher toward the east, with shells of gastropod and pelecypod, relatively high raised beach terraces or ridges mostly composed of thin bands of black sand alternating with white layers bands. The backshore zone extending inland from the beach is rather flat, extensive especially in the west, wet with frequent vegetated small sand heaps or nebkas (Fig. 1.4). Petrographically, it is rather complex comprising coastal sabkhas, playas of silty soil, salt pans, relicts of old beach ridges, and sand

sheets westwards and sand dunes eastward.

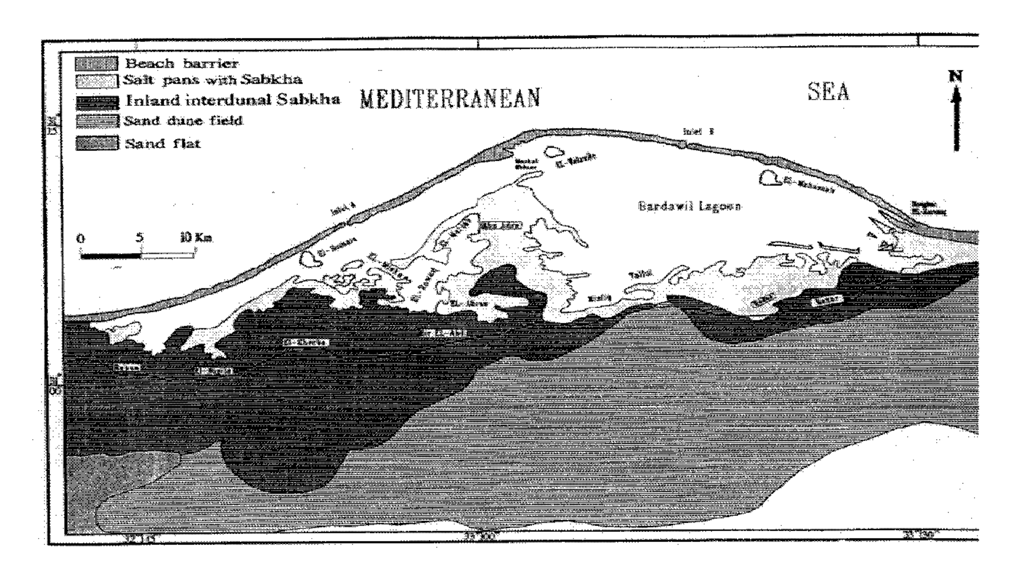


***Fig. 1.4.* Geomorphological units of Bardawil Lagoon area (Khalaf *et al.* 1997).**

1.3.1.2 Sand bar

The shore that separates the Bardawil Lagoon from the Mediterranean Sea is a thin crescent sand bar with the convex side toward the sea. The bar is long and narrow about 50 km long and less than half a kilometer wide. It is dissected by Boughaze El-Zaranik to the east which is an older natural tidal inlet and two man-made inlets (inlets 1 to the west and inlet 2 to the east). These inlets form at present the main connection with the Mediterranean Sea. They have few hundred meters breadth, bordered by loose fine yellow beach sand alternating with grey to dark black sand bands and marine shells. Sand barrier slopes very gently toward the sea, favoring its formation through sediment transportation landwards by waves. A few trenches were made north of Bardawil Lagoon. They indicated an upward sequence made up of alternating nearly horizontal laminae of yellow and black sands with dominant shells and plant remains sand gets coarser upward. The beach north of Bardawil Lagoon is sandy and rich in pelecypod and gastropod shells and other marine organic remains. In Sebikah pond eastward, a clay bed was found directly below a vast salt crust.

1.3.2 Lagoonal Landforms

1.3.2.1 Bardawil Lagoon

Bardawil Lagoon covers an area of about 600 km^2 with about 80 km long and 20 km maximum width. It is a shallow water lagoon with irregular bottom topography (Gaafar 1991). It varies between zero and 220 cm with an average of about 117 cm depth (Fig 1.5). The maximum depth at present lies to east of

inlet 1, whereas the minimum is encountered along the southern shore of the lagoon and is often inhabited by mixed submerged aquatic plants. The prevailing wind which affect the water of the lagoon blows from NNW most of the year. Current velocity varies between 15.1 and 16.8 cm sec^{-1}. So, wind generated currents propagate in south east direction. Field observation (Gaafar 1991) indicate that the coastal drift currents and circulation system are directed from east to west in the southern part and turn from west to east at the northern part of the lagoon (i.e. clockwise direction: contrary to the anticlockwise current of the Mediterranean). Bardawil Lagoon is one of the important fish producing lagoons along the northern coast of Egypt. Moreover it is the least polluted because no drainage canals discharge water in it. Its water is highly saline showing multicolours due to the presence of different genera of biota, algae and other organic material. The colour of water varies from dark green to even violet.

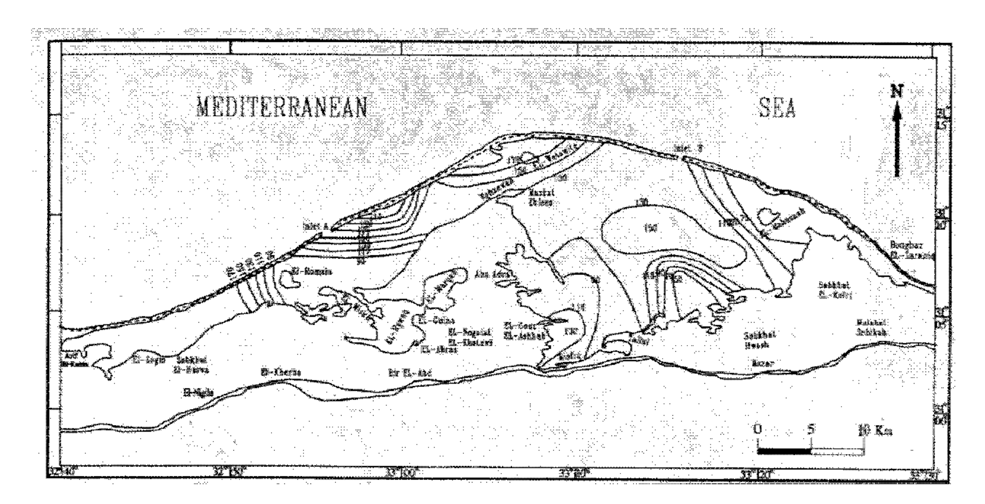


Fig. 1.5. **Bottom configuration of Bardawil Lagoon, depth in centimeters (Gaafar 1991).**

A narrow channel called El-Miska joins the Bardawil Lagoon with El-Rowaq inner lagoon, where a shell bed occurs at about 40 cm deep extending for few kilometers in a NE direction, then it disappears at about 6 km to the southwest of Maskat Eblees. The attached Rowaq and Marqab inner lagoons (ponds) are prominent geomorphologic features of Bardawil complex lagoon. They become almost isolated small lagoons, especially in summer when the supply of water through El-Miska is limited. Hence they become of higher salinity with frequent organic material and consequently called locally Mallaha, as Malahat Sebikah in the east.

Nodular banded 40 - 60 cm thick gypsum layer, mixed with halite occurs on the eastern side of El-Rowaq and along the northern and western shorelines of El-Marqab. To the east of El-Marqab inner lagoon, another shallow small

pond is present surrounded by islands (e.g. Um El-Ishi and Um El-Kamma). Around this pond, an evaporated layer of 20 - 40 cm thick occurs.

1.3.2.2 Inlets (Boughazes)

Bardawil complex lagoon is connected to the Mediterranean Sea by three main inlets or canals for water exchange. Inlet "1" is the artificial western inlet which is north Mersa El-Rowaq. This inlet is 600 m long, 150 m wide and 4-6 m deep, its western side is rather developed and has gentle slope. Waves and current cause erosion of the eastern side and deposition of coarse sands on the western side. Inlet "2" is an artificial inlet; it has a central position and is also subjected to erosion on the eastern side and deposition on the western side (similar to inlet "1") due to the jetties constructed for their protection. Both inlets 1 and inlet 2 are protected with constructed jetties and are kept open by dredging of accumulating coarse sand in order to keep the inlets open and to preserve fish life in the lagoon. The third and fourth inlets present on the eastern side of the Bardawil Lagoon: Boughaze Abu Saleh (30 m wide and 2 m deep) and Boughaze El-Zaranik (20 m wide and 1 m deep), are natural inlets and are sometimes blocked by deposition. The artificial tidal inlets play an important role, particularly in winter and spring by allowing tide waves to invade the lagoon and decrease its salinity that strongly rises in summer.

1.3.2.3 Islets

Bardawil Lagoon is characterized by approximately 51 islets, some of which are elongated, oriented subparallel or normal to the present coast and of few kms in diameter. They comprise a total area of about 3170 Feddan which approximates 1.9% of the lake area (Gibali 1988). These small islands include El-Mahasnah in the north eastern part of the Bardawil Lagoon, El-Watawite in the north central part, El-Gouz El-Ashhab in the south and El-Romaia in the western arm of the lagoon. These islands are mostly made of muddy sand, covered by vegetation. A mud surface layer with dense vegetation occurs in El-Mahasnah Island. El-Romaia Island is about 2 meters above sea level and covered with sand sheet and scattered vegetation.

1.3.2.4 Sabkhas and salt pans

Supratidal salt flats cover the southern and eastern parts of Lake Bardawil. This is normally described as "Sabkha" (Kinsman 1969, Till 1978). In terms of geomorphology, coastal sabkha is simply the analogy of the salt marshes of temperate zones (Selly 1982), where marsh areas are poorly drained with permanent high water table and distinct assemblages of grass vegetation. Around the Bardawil Lagoon, two types of sabkhas are distinguished; beach or coastal flat sabkhas and inland or continental sabkhas. The coastal sabkhas are occasionally flooded by lagoonal water especially during winter storms (i.e. they mostly have marine connection). Inland sabkhas, on the other hand, occupy

depressions between sand dune ridges and are completely separated from the lagoon. They are fed by meteoric water seepage from surrounding dunes after local rains and are subjected in varying degrees to upward percolation of ground waters and brines. Different core samples of sabkha were raised to disclose their lithology variation with depth up to 1 m below the ground. A layer of fine crystalline gypsum was usually found at 10-30 cm deep from the surface occasionally covered with black carbonaceous mud.

At El-Khatawi, south east El-Rowaq and El-Marqab, beach sabkha may form a surface pavement of sandy evaporite incrustations and modules, with a silt layer at a depth of 50 cm. Sabkhet Hawash, east of El-Telul, is another example of beach sabkhas with central saline water body producing salts by evaporation. In this sabkha large crystals of gypsum and halite are developed. The crystallization of such gypsum and halite crystals reflects the highly restricted hydrographic conditions of this sabkha located south Bardawil Lagoon. In the southern sabkha regions, halite predominates with the continuous evaporation process.

In the few cores raised from the sabkhas, clay beds have not been penetrated. However, boreholes drilled in the neighboring coastal areas of Sinai (e.g. Rafah and Sheikh Zouyed) penetrated clayey beds (Fink 1969, Zelinger *et al.* 1971). These authors believe that the sabkha brines are retained near the surface by the underlying impermeable clay bed. Inland sabkhas are rather common and distributed in lowlands between the sand dunes. Some authors describe them as playa (Khalaf *et al.* 1997) commonly occurring at Rabaa, El-Kherba, Bir El-Abd and El-Mazar, around the main asphaltic road to El-Arish.

1.3.3 Aeolian Landforms

1.3.3.1 Sand dunes

The characteristic morphology of northern Sinai as a wide low lying plain permits winds to carry aeolian sands and accumulate them within this coastal plain and around the cliffs of nearby hills. The peripheries of numerous coastal sabkhas or wet flats generally act as traps for wind blown sand. The sand movement and dune morphologies in northern Sinai are controlled by the prevailing SW and W winds changing to NW in winter (Ganor *et al.* 1973). The dunes in this region are almost parallel to the Mediterranean coast and extend, more or less, E-W for a considerable distance.

The dune intensity and elevation tend to increase eastward, reaching a maximum width of about 3 km near Rafah, but south of Bardawil Lagoon, the average height of the dunes is about 20 m, average width about 50 m and average length about 400 m. Misak and Attia (1983) distinguished two types of dunes in north Sinai (mostly of beach origin, brought by sea-water during high tides): crescentic transverse dunes (i.e. barchan dunes) mostly in the eastern part (formed by SW and W winds), and NW and NE extending complex parabolic

dunes (common at El-Mazar, Bir El-Abd and Romana). However, migration of these chain of sand dunes landward is a natural hazard that threatens native settlements. Therefore, effort is made for fixing them using wood fences and palm plantation. Furthermore, these dunes act as reservoirs of fresh water for drinking and local irrigation. Nevertheless, these sand dunes form at present one of the chief obstacles for the development of north Sinai area, since they occasionally encroach upon main roads, cultivated lands and the water wells near the coast. In general, it is important to mention that the coastal morphology changes with time by the aeolian sediment transport, a process which could be inhibited when the coastal dune ridges and backshore sand sheets are stabilized by vegetation. However, it has been observed that sand sheets prevail mainly in the south-western part, whereas the sand dune field ridges dominate toward the east, usually alternating with sabkha or playas.

1.4 CLIMATE

The Mediterranean coastal land of Egypt belongs to the dry arid climatic zone of Koppen's (1931) classification system (as quoted by Trewartha 1954). In general, the study area has a narrow range of variation for most of the climatic variables. The mean annual temperature varies between 20.5 °C at El Arish and 21.1 °C at Port Said. January is the coldest month with a mean temperature that varies between 13.6 °C at El Arish and 14.2 °C at Port Said (Table 1.1 and Fig. 1.6). On the other hand, August is the hottest month with mean temperature that varies between 27 °C at El Arish and 27.3 °C at Port Said. Annual relative humidity varies between 68% at Port Said and 70% at El Arish. Annual evaporation rate varies between 4.5 mm/day at El Arish and 6 mm day^{-1} at Port Said. The distribution of the mean annual rainfall in Egypt (Griffiths 1972) shows a maximum close to the Mediterranean coast (192.1 mm year^{-1} at Alexandria, 104.7 mm year^{-1} at El Arish) and then decreases rapidly towards the south. In this region, the rainfall gradient is associated with an inverse evaporation gradient which indicates the increase of aridity from north to south.

The mean annual total sky cover varies between 1.6 oktas in Port Said (with a minimum of 0.8 oktas in June and July and a maximum of 2.7 oktas in December and February) and 2.5 oktas in El-Arish (with a minimum of 1.2 in June and a maximum of 3.6 oktas in February). The mean scalar wind speed varies between 4.6 knots in El-Arish (with a minimum of 3.9 knots in October and a maximum of 5.8 knots in March) and 9.0 knots in Port Said (with a minimum of 7.4 in August and September and a maximum of 11.3 knots in March) (Fig. 1. 7).

Table 1.1. **Monthly variation in air temperature (°C), relative humidity (RH%), evaporation (EV: mm day^{-1}), rainfall (RF: mm month^{-1}) mean scalar wind speed (knots) and total sky covers (oktas) as recorded by Port Said and El-Arish metereological stations (Anonymous 1980).**

Month	Port Said								El Arish							
	RH	EV	RF	WS	TSC	Temperature (°C)			RH	EV	RF	WS	TSC	Temperature (°C)		
						Min	Max	Mean						Min	Max	Mean
Jan	71	4.5	13.5	9.3	2.6	11.2	18.1	14.2	70	3.6	20.3	4.8	3.1	8.5	19.2	13.6
Feb	68	5.5	11.7	10.0	2.7	11.8	18.8	14.7	69	4.0	17.1	5.7	3.6	9.1	19.9	13.9
Mar	66	6.2	8.8	11.3	2.9	13.3	20.4	16.4	64	4.5	12.8	5.8	3.2	10.8	21.3	16.0
Apr	69	6.2	3.7	10.4	2.1	15.6	22.6	18.7	67	4.7	6.1	4.9	3.1	13.3	23.7	18.7
May	69	6.5	2.2	9.4	1.7	19.1	25.7	21.8	68	4.9	3.2	4.7	2.2	16.1	26.9	21.6
Jun	70	7.1	0.0	9.0	0.8	22.2	28.6	25.0	72	4.9	0.0	4.6	1.2	18.9	28.9	24.7
Jul	71	7.1	0.0	8.4	0.8	23.8	30.4	26.6	74	4.8	0.0	4.4	1.4	21.3	30.6	26.2
Aug	71	7.0	0.0	7.4	1.0	24.4	30.9	27.3	75	4.9	0.2	4.1	1.6	21.9	31.1	27.0
Sep	68	7.2	0.2	7.4	1.1	23.5	29.5	26.1	71	5.2	0.6	4.2	2.2	20.4	29.9	25.6
Oct	68	7.0	6.3	8.0	1.5	21.4	27.4	24.3	73	4.8	6.0	3.9	2.5	18.0	28.5	23.2
Nov	70	6.0	8.9	8.3	2.3	18.0	23.9	20.6	71	4.0	16.2	4.0	2.7	14.4	25.3	19.7
Dec	71	4.6	18.0	8.4	2.7	13.1	19.9	16.0	66	3.6	22.2	4.7	2.9	10.2	21.4	15.5
Mean	**68**	**6.0**	**6.1**	**9.0**	**1.6**	**17.8**	**25.4**	**21.1**	**70**	**4.5**	**8.7**	**4.6**	**2.5**	**15.2**	**25.6**	**20.5**
S.D.	**1.5**	**0.9**	**5.8**	**1.1**	**0.8**	**4.8**	**4.5**	**4.7**	**3.2**	**0.5**	**8.1**	**0.6**	**0.7**	**4.7**	**4.2**	**4.7**

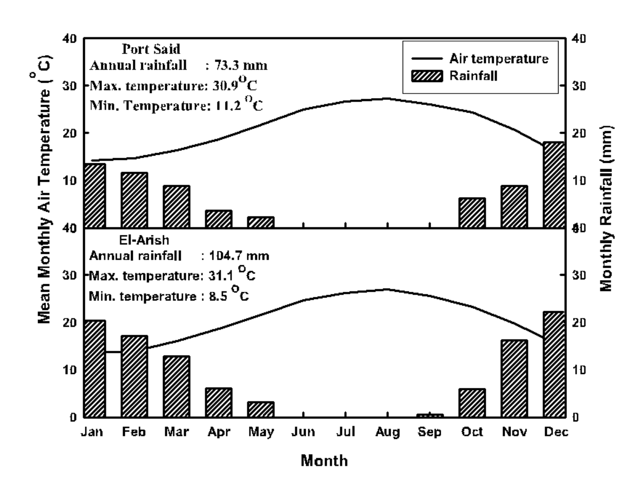


Fig. 1.6. **Climatic diagrams of Port Said and El-Arish meteorological stations.**

1.5 HABITAT TYPES

Considering the landforms in Lake Bardawil (Shaheen 1998) and the biota that inhabit them, 6 major habitats are clearly distinguished:

1. Open water

Lake Bardawil has extensive areas of open water, all are shallow with 0.5 to 1.5 m deep and no emergent vegetation, but with patches of sea grass *Ruppia cirrhosa* and filamentous green algae growing on the mainly sandy bottom. The thick patches of *Ruppia* consist of a series of narrower waterways threading between islands and mudflats. In October, the extent of open water in this part of the system may be at a seasonal minimum. These waterways connect with the Mediterranean Sea via four narrow inlets (i.e. Boughaze) through the sand bar.

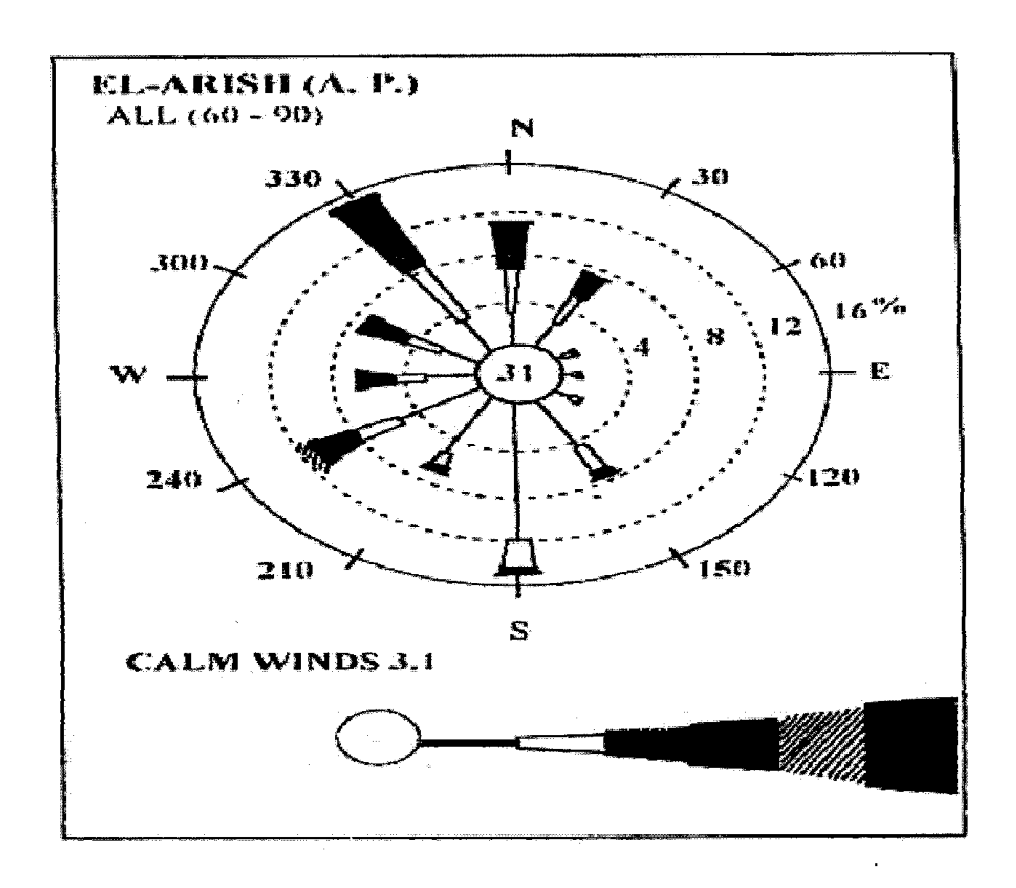


Fig. 1.7. **Wind rose diagram at El-Arish (Shaheen 1998).**

2. Mudflats

In some areas there is a substantial accumulation of silt among the sand to create extensive areas of mudflats. These are most common in Lake Zaranik (the eastern arm of Lake Bardawil). In some areas the mudflats are completely blanketed with an algal mat, and this mat can be fragmented into pancake-like patches. These patches may peel away from the underlying mud to provide a broken surface which in some situations appeared to be particularly attractive to birds. Such broken surfaces occurred on both wet and dry mud.

3. Stabilized sand dunes

They extend along the southern limits of Zaranik Protectorate from Maaden zone near Al-Midan village to the east until the eastern coast of Zaranik Lake. Most of sand dunes in this area are not active, their density becomes less as we go to the south of the Protectorate, the features of senility appeared on them as they cannot move and are exposed to the different weathering and boring process. The presence of salt marshes and halophytes are among the most important reasons of the arising of such types of dunes, as the increase of evaporation from the marshes leads to the formation of salt crust on the surface

of the dunes which prevents their movement, in addition to the existence of a dense cover of halophytes which withstand high salinities in the inter-dunes depressions.

The sand dunes in Zaranik Protectorate take two principal axes: the first axis extends from the northwest to the south east (appears in the south east in the area between Sebeka and Mazar, their lengths are between 250-300 meter), the second axis extends in an east-west direction (they spread in the south-west side of the Protectorate North of Rawdah and El-Tulol marsh, their lengths are from 150 m to 2 km). The distance between each other is about 700 m. The axes of these dunes go along with the direction of northwestern wind, which predominate in the region.

4. Mobile sand dunes

Wavy sand arises as a result of the operation of fast sedimentation over the sea level. The wind force and direction have a great effect on the morphological shape of the sand waves, as the wind force affects the length and regularity of the waves. The steadiness of the wind direction makes the wavy sand perpendicular on it, while the change of the wind direction leads to change the shape of the waves and make them irregular. The wavy sand spreads in the study area, especially on the surfaces of the sand dunes. In general they are perpendicular with the wind direction. Regular wavy sands are formed due o the steadiness of wind velocity and direction, thus they are characterized by relative straightness and debate with the wind direction. On the other hand, irregular wavy sands are affected with the change in wind velocity and direction which lead to the distortion in the shape of the wavy sands.

Barchans are prevalent sand dunes in Zaranik Protectorate. They are broad dunes with bended edges as a result of the action of unidirectional wind. The sand grains which move over the body of broad sand dune must cut larger distance when they cross its middle parts, while the grains that move over the edges cross a shorter distance, and due to this the dune edges move faster than the middle parts. Thus, barchans have, more or less, an arc or crescent shape in which the convex side is directed to the windward, while the two edges are directed to the leeward. The increase of temperature and drying up of the beach sand facilitate the sand transportation, especially in the time of tide and exposition of beach areas.

Nabkas spread between the sand dunes in the north and salt marshes in the south. The existence of marshes helps in the growth of halophytes and their spreading in the neighboring zones. The medium dimensions of the nabkas are about 3.0 m length, 0.7 m height and 2m width. The elevation of the nabkas windward slope is due to the tenacity of the sediments of this side and the increase of humidity due to closeness from the salt marshes.

5. Salt marshes

The salt marshes represent a great proportion of the Zaranik wetland. Their areas differ greatly from small areas of not more than several square meters to big ones which reach about 50 square kilometers. The marshes are fewer in the south and have different shapes (e.g. elongated or circular shapes). In some zones, there are sediments of silt and sand. The coastal marshes in the Protectorate are divided according to their level into 2 types:

a) Coastal marshes higher than the sea level; these are distributed in a continuous way from east to west (e.g. marshes of Abu Fleifel, Abu Mazrua, El-Saee, Sebeaka, El-Koufry and Berket El-Gamal). Their level can rise in some points by one meter over the sea level and some sandy valleys permeate through them reaching 14 meters levels.

b) Coastal marshes lower than the sea level; these marshes occupies about 0.9 % from the total area of the Protectorate. They are 18 marshes, having areas between 400 square meters and 2.5 square kilometers. Hawashi marsh is the biggest with an area of 2.4 square kilometer. The Coastal marshes are considered as ecological units of distinctive biotic (e.g. plants and animals) and abiotic characteristics. Some of these marshes are utilized as saltpans, which extend from east to west (e.g. Draa El-Deeb, Sebeaka, Mekhazan, Mekhazan El-Olwy). The area of these marshes is about 0.6 square kilometer.

The sabkhas of Lake Bardawil are developed in the intertidal- supratidal zone occupying low topographic areas south El-Bardawil lagoon. They are almost dry in summer and temporarily wet in winter with sporadic saline pond at the center. Core samples reveal fine-grained sediments varying in composition from calcareous sand, muddy sand and sand mud, with a general upward increase of organic carbon (Fig.). Thin layer of crystalline gypsum is encountered at depth of 10-30 cm from the surface; occasionally covered with black algal mat. Halite occurs mainly as thin encrustations on these sabkha – evaporite complex (Shaheen 2003).

Mineralogically, the sabkhas are composed dominantly of quartz sand, gypsum, calcite and halite, whereas feldspars and dolomite are rare. Clay minerals are mainly kaolinite, montmorillonite and illite.

Brine water of the sabkhas has a pH range of 7.0-8.0 and a salinity range of 82.8-326.0 g/L. The salinity values reflect the arid climate of the area and the sea–water seepage from the lagoon (Shaheen 2003). The ranges of cations in meq/L are: Na^{+} = 644.8-3604.1, K^{+} = 15.3–166.2, Mg^{++} = 695.8–1740.0, and Ca^{++} = 164.0– 525.0. The ranges of anions in meq/L are: Cl^{-} = 1360.0–5591.5, SO_4^{--} = 48.3–317.7 and HCO_3^{-} = 3.0–4.6 (Table).

The coastal sakhas are occasionally bounded by a belt of low relief vegetated nabkhas mostly covered with *Artemisia monosperma*. Their surface crust is characterized by thin horizontally bedded carbonaceous matter. The presence of alternating horizontal bedded laminae of clastic sand of light to dark

color suggests the seasonal climatic changes affecting the coastal sabkhas. This points to alternating periods of water floods that cover the surface of the sabkhas and others at which sabkhas get dry and subject to the deflated sand dunes.

Table1.2. **Chemical analysis of the brine water samples collected from some coastal sabkhas at Bardawil wetland (Shaheen 2003).**

Locality	pH	EC	TDS	Cations (meq/l)					Anions (meq/l)			
		(mS cm^{-1})	(g/L)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Total	Cl^{-}	SO_4^{-}	HCO_3^{-}	Total
El-Haswa	7.1	302.0	165.8	220.0	1579.2	1056.0	166.2	3021.4	2709.3	317.7	3.0	330.0
El- Abass	7.0	152.0	83.8	164.0	695.8	644.8	15.3	1519.9	1360.0	155.8	3.0	1518.8
Abu Adra	7.2	405.5	218.3	525.0	1708.3	1778.7	46.0	4058.0	4000.0	48.3	4.1	4052.4
Misfiq	8.0	225.0	123.0	356.0	991.7	884.3	27.6	2259.6	2126.8	127.5	4.6	2258.9
El- Kofri	7.2	582.0	326.7	322.0	1740.0	3604.1	163.6	5829.7	5591.5	233.3	1.8	5827.1
Mean	**7.3**	**333.3**	**183.5**	**317.4**	**1341.0**	**1593.6**	**83.7**	**3337.7**	**3157.5**	**176.5**	**3.3**	**2797.4**
SD	**0.4**	**167.8**	**94.4**	**139.3**	**371.5**	**1200.9**	**74.9**	**1680.4**	**1668.0**	**103.0**	**1.1**	**2166.0**

6. Sand hillocks

An adaptive feature of the growth of psammophytes and halophytes in semi-arid and arid regions throughout the world is the accumulation of wind-borne sediments with or around their canopies (Batanouny 2001).The formation of such phytogenetic hillocks (the desertic analogy is nabkas) creates patches where microclimate and soil) properties are different from inter-nabka patches.

Nabkas of woody shrubs affect the growth and diversity of associated species as they represent fertility island for many species (El-Bana *et al* 2002). Nabkas formed around many psamnophytes and halophytes are abundant throughout North Sinai. The most prominent nabkas in north Sinai are there of *Retama raetam* and *Nitraria retusa* (Gibali 1988) particularly in some of the islets of Lake Bardawil (e.g El-Flusiyat and El-Malty: El-Bana *et al.* 2002, 2003).

The comparison of the soil texture on *Ratama raetam* nabka microsites and in the inter-nabka space in some islets of Lake Bardawill (El-Bana *et al* 2002) showed that the soil in the inter-nabka space was sandier. On the other hand, the nabka microsites fine fractions (silt and clay) were significantly higher than those of the inter-nabka spaces. For instance, silt content was four times higher on the nabka crest (4.6 %) than in the inter-nabka space (1.1 %). The soils at the nabka edges had significantly higher concentrations of organic carbon and total N. Soil pH and $CaCO_3$ content were not significantly different among the four microsites. Electrical conductivity and cations were also higher in soils at the nabka edges than in soils of the inter-nabka spaces (Table). However, there were no differences in soil texture and nutrients between soil from the nabka crests and midslopes.

Table 1.3. **Comparisons of soil variables at nabkha crest, midslope, edge, and nabkha inter-space. Values in a row with different letters are significantly different according to Tukey's studentized range test at the 0.05 probability level (El-Bana *et al.* 2002).**

Soil Variable	Crest	Nabka Midslope	Edge	Nabka inter-space
Sand (%)	93.5[a]	94.6[a]	96.7[b]	98.7[c]
Silt (%)	4.6[a]	3.8[a]	2.9[a]	1.1[b]
Caly (%)	1.9[a]	1.6[a]	0.4[a]	0.3[b]
$CaCO_3$ (%)	3.1[a]	3.1[a]	3.1[a]	3.0[a]
pH	7.9[a]	7.7[a]	7.8[a]	7.7[a]
EC (mS cm^{-1})	0.6[a]	0.6[a]	0.7[a]	0.5[b]
Organic carbon (%)	0.3[a]	0.3[a]	0.4[b]	0.2[c]
Total N (μg g^{-1})	32.9[a]	33.2[a]	44.8[b]	25.4[c]
P (μg g^{-1})	27.4[a]	26.9[a]	29.4[a]	23.7[b]
Na (μg g^{-1})	95.8[a]	104.2[a]	120.1[b]	65.4[c]
K (μg g^{-1})	31.4[a]	32.9[a]	48.1[a]	17.7[b]

A generalized cross-section of the habitat types occurring at Bardawil Lake is shown in Fig. 1.8 (Varty 1990). Dunnet *et al.* (1985) recorded the distribution of these types of habitats as follows: 45% sandy shore, 18% mudflats and 37% halophyte-dominated shoreline; compared with the results of another survey in October 1989 (28%, 13% and 60%, respectively).

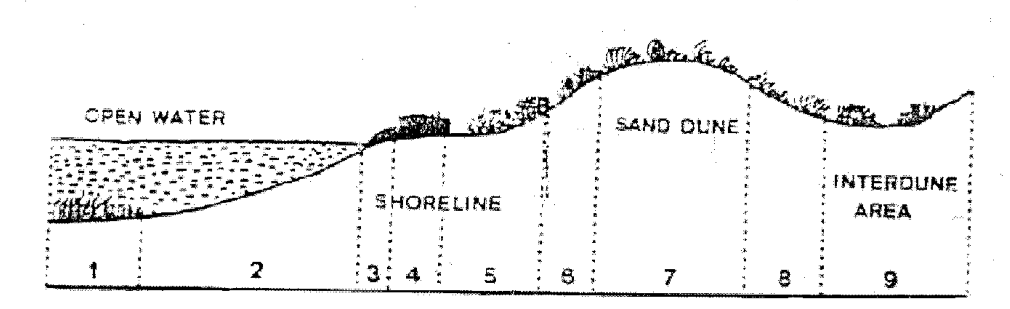


Fig. 1.8. **Generalized cross section of the shallow waters and shores of Lake Bardawil showing major habitat and vegetation types (after Varty 1990). 1: dense growth of *Ruppia cirrhosa*, 2: sandy bottom of varying width, 3: accumulation of dead *Ruppia* remains, 4: halophytic vegetation dominated by *Sarcocorinia fruticosa*, *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum*, 5: sandy area separates the *Sarcorinia* community from *Zygophyllum album* community, 6: mixed community of *Zygophyllum album* and other species (depending on the slope of the adjacent sand dunes), 7: some species dominate the upper part of the sand dunes (e.g. *Cornulaca monacantha*, *Stipagrostris scoparia*, *Artimisia monosperma*, *Nitraria retusa* and *Thymelaea hirsuta*) and 8 and 9: *Zygophyllum album* and less frequently *Sarcocorinia fruticosa* growth in the interdune areas where the water-table reaches the surface.**

Although no detailed studies have been made, it is likely that the extent and distribution of the various habitat types of the lagoon vary according to the hydrological circumstances: the area of open water being at a minimum in late summer and a maximum following the winter and spring rains (Varty1990).

1.6 HYDROLOGY

1.6.1 Characteristics of the Catchment Area

The catchment area of Zaranik Wetland (Fig. 1.9) as a part of Lake Bardawil is located between latitudes 30° 30̀ - 31° 13̀ N and longitudes 32° 30̀ – 33° 47̀ E. The altitudes of the catchment area vary from zero level at the Mediterranean in the north to about 651 meter above sea level at the most southern edge at Gabal Al-Rokba (Al-Maghara area). Its surface slope in the catchment is northwards with an average slope of 0.0125 m m^{-1}. El-Shinnawy (2002) estimated its size as to cover about one tenth of the whole area of Sinai (about 6000 km^2 that equals about 1,428,000 Feddan including the lagoon).

The catchment area has a wavy topography in the north side, while it has a mountainous nature in the south. Dunes have no definite orientation but there is an obvious NW-SE linear pattern toward the southwestern parts of the area. Wind erosion aided in rounding the dunes and forming elongated NW-SE oriented ridges. Northwards of the area close to the Mediterranean, tidal marshes cover large parts. They form salt lakes mostly connected to Lake Bardawil. The depressions are covered by sabkha deposits due to seepage from sea water. Brine water covers some parts of sabkhas especially in winter, and salt crust cover vast areas to the south of Lake Bardawil. Palm trees are scattered in areas close to the sabkhas and also over dunes. Agricultural areas found in low lands. However, smaller scattered cultivated areas are found wherever water is available.

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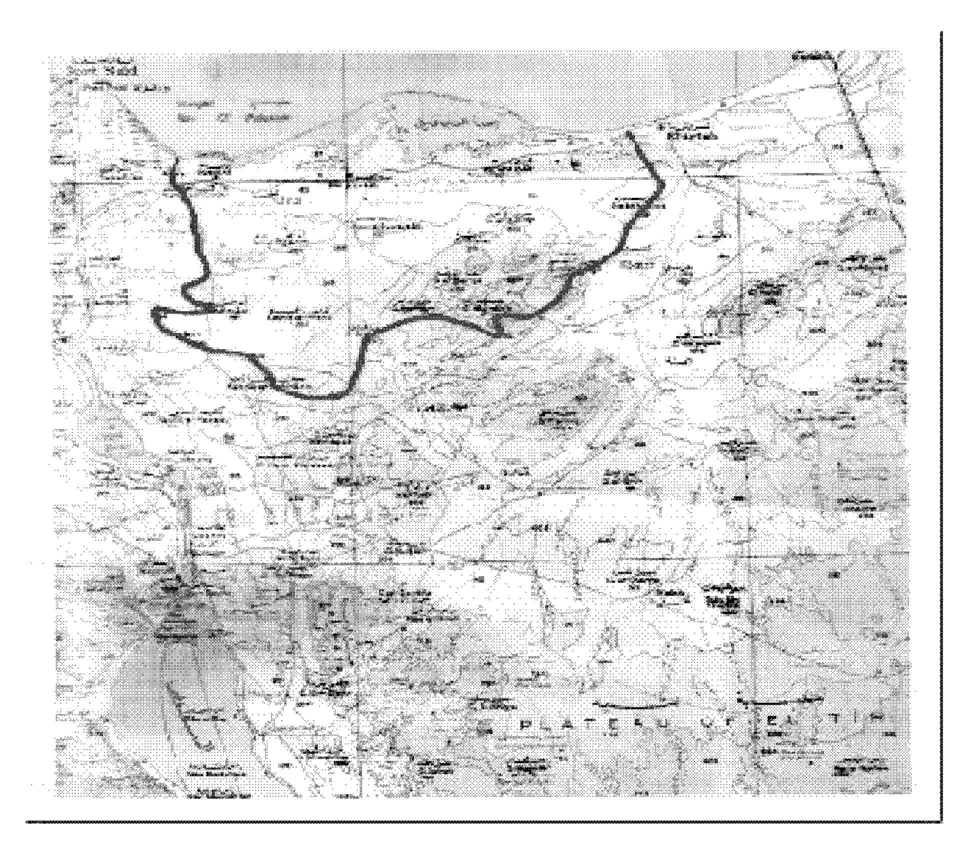


Fig. 1.9. **Catchment Area of Bardawil Wetland (El-Shinnawy 2002).**

1.6.2 Water Resources in the Catchment Area

Water resources in the catchment area are rainfall and groundwater aquifers. Rainfall feeds and recharges the unconfined groundwater aquifer.

1.6.2.1 Rainfall volume

Mean annual rainfall distribution over Sinai demonstrates that the mean annual rainfall varies from about 100 mm to about 65 mm. The catchment area receives a mean annual depth of rainfall of about 80 mm. This produces an annual rainfall volume of about 478 million m^3. About 2% of this volume goes back to the atmosphere during the rainfall storms causing minimum losses of evapo-transpiration. The rest of the rainfall volume feeds the groundwater aquifer system; especially the unconfined aquifer that is the main aquifer system in the catchment area.

1.6.2.2 Hydrogeology

1.6.2.2.1 Quaternary aquifer

Qaternary aquifers are hydraulically connected; hence they are considered one aquifer. This aquifer extends along the coastal area of the Mediterranean Sea from east to west with about 30 km width. The following provides lithologic description from top to bottom in sand dunes with thickness of about 20-30 meter, the upper 5 meters are recent mobile dunes followed by the stabilized type; this layer stores fresh water of rainfall from Bir Al-Abd in the west to Rafah at the east; the second layer of the Quaternary aquifer is the gravel or wadi deposits layer, the thickness of this layer is about 30 meters. The third layer is the calcareous sandstone with a thickness of 20-40 meters.

1.6.2.2.2 Hydraulic parameters of the Quaternary aquifer

Quaternary sediments are distributed along the coastal plain and wadi beds. Some test wells were drilled to evaluate the different hydraulic parameters and the extension of the Quaternary by different authorities (El-Shinnawy 2002). Studies revealed that the sand dunes were the main aquifer at the south of Lake Bardawil. The top 4-6 meters are mobile sand and the lower part (6-20 meters) is the major aquifer. Analysis of pumping tests indicated that the permeability coefficient value ranged between 293 and 456 m day^{-1}, the transmissivity ranged between 1469 and 2283 $m^2 day^{-1}$.

1.6.2.2.3 Water levels of the Quaternary aquifer

Groundwater levels are one of the key information for its resources assessment and management. The water levels of the Quaternary aquifer were measured since 1954 in a small number of wells. Since 1982 more studies were carried out and continuous monitoring was taking place on a monthly basis by Water Resources Research Institute. Monthly iso-potentiometric maps are created to allocate water levels at concerned study areas. Measurements for the Quaternary aquifer reveal that water level in the phereatic aquifer (unconfined) fluctuates and changes directly with rainfall, the highest levels take place after the rainfall season. The highest level recorded was a 13.9 m and the lowest level was –1.5 m in the areas around the sabkhas to the west of Lake Bardawil. Actually, groundwater flows from south toward north and northwest. The level of water table ranges from +3 m to +0.5 m. This means that the Quaternary aquifer contributes to Lake Bardawil as well as to Zaranik wetland.

1.6.2.2.4 Groundwater utilization

Groundwater is mainly abstracted for domestic uses. Abstractions for industries probably use a minor part of the total abstraction. Shallow wells operated by hand pumps are still extensively used for domestic purposes, especially in the rural areas of the catchment area. Shallow wells may have depths from 15 to 40 m below ground surfaces. Hand pump wells are usually drilled until sandy or gravelly sediments are reached, which often coincides

with the top of the aquifer. The behavior of the aquifer in the dune system provides a measure of the discharge and recharge process. The recharge was estimated at 38,000 m^3 day^{-1} and the discharge from the aquifer was estimated at 14,000 m^3 day^{-1}. As a result, the net recharge is about 24,000 m^3 day^{-1}. This volume represents the life body of water that result in water flow to Lake Bardawil.

1.6.2.2.5 Groundwater quality in the catchment area

As the main source of water in the dune aquifer system comes from rainfall and there are no pollution sources so far, the water quality is expressed in total dissolved solids. Previous studies revealed that water salinity in the aquifer varied from 2000 ppm at the south border to about 7000 ppm close to the sea. The reason that salinity increases northward is due to seawater intrusion (El-Shinnawy 2002).

1.6.2.2.6 Hydrodynamic processes in Bardawil area

The hydrodynamic processes are illustrated by a simplified model in order to explain the formation of sabkha-evaporite complex, especially the supratidal zone around Lake Bardawil (Fig. 1.10). The lagoon, however is mainly recharged by sea water floods through the inlets, especially in winter and spring. Occasional rainfall in winter is another source of water recharge of the lagoon and the surrounding sand dune field (Shaheen 1998). Precipitation may also recharge groundwater seepage particularly in the interdunal depressions in the supratidal zone. Sabkhas and diagenetic evaporites are frequent in these depressions and around the lagoon, being developed by evaporation under dry conditions, especially in summer. At present, no streams or drain water discharge into the lagoon. A mixing zone is expected to exist at the southern shoreline of Bardawil Lagoon, in this zone fresh ground water accumulating at bottom of the sand dunes could be mixed with the saline water of the lagoon.

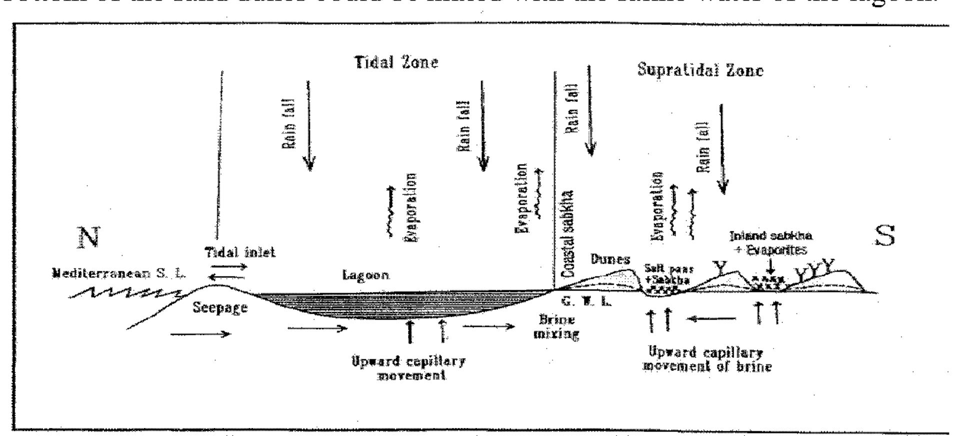


Fig. 1.10. **Simplified model for hydrodynamic processes and sabkha-evaporite formation in Lake Bardawil (Shaheen 1998).**

1.6.3 Water Resources

1.6.3.1 Rainfall

Rainfall data recorded at El-Arish and Port Said were used to estimate the rainfall depths at Zaranik. Analysis indicates that the mean annual rainfall over the area is 92.5 mm (Table 1.4). This depth of water provides the wetland with mean annual volume of about 15.7 million m^3. Analysis also demonstrates that most rainfall takes place during the winter season (October – March). The area does not receive rainfall in the summer months. The maximum depth of rainfall is received in December and January.

Table 1.4. **Monthly volume of rainfall, evaporation and salt production requirements (10^6 m^3) in Bardawil Wetland (El-Shinnawy 2002).**

Month	Rainfall (10^6 m^3)	Evaporation (10^6 m^3)	Salt production (10^6 m^3)
January	3.2	18.5	15.3
Febrauary	2.7	19.2	15.8
March	2.0	23.5	19.4
April	1.0	25.0	20.7
May	0.4	27.4	22.7
June	0.0	28.4	23.5
July	0.0	30.4	25.2
August	0.0	29.9	24.8
September	0.1	28.1	23.2
October	0.8	26.7	22.1
November	2.4	23.5	19.4
December	3.2	21.6	17.9
Total	15.7	302.7	250.0

1.6.3.2 Evaporation

Evaporation measurements by Al-Nasr Salt Production Company in the wetland have been collected. The average value for daily evaporation in each month was used to calculate the monthly evaporation. The monthly values of evaporation have been transformed to volumes of water losses from the wetland considering the surface area of the water body in the wetland (68% of 250 km^2). To involve evaporation losses in the water balance equation, time interval was introduced and considered. The total volume was estimated to be as much as 302.1 million m^3 yr^{-1} (Table 1.4).

1.6.3.3 Salt production requirement

Al-Nasr Company for Salt Production discharg about 25 million m^3 of water from the wetland to salting basins. This volume is divided over the year according to the evaporation rate (Table 1.4). The maximum amounts are discharged during the summer months (25.2 x 10^6 m^3 in July and 24.8 x 10^6 m^3in August), while the minimum are discharged during the winter months (15.3 x 10^6 m^3 in January and 15.8 x 10^6 m^3 in February).

1.6.3.4 Tidal effect

According to field measurements during investigation period, the tide at Zaranik wetland was estimated as the difference between the mean high water level and the mean low water level. Although the difference is small, it affects water level in the lake in case of high wind speed. Measurements indicate that the tide ranges between 25 and 35 cm. An average of 30 cm was considered as a small depth that has little effect on water balance in the wetland. As a result, it is concluded that the tidal effect is small.

1.6.3.5 Human activity

The human activities are represented by outflow and inflow of water from or to the wetland by local communities in the surrounding areas. Social studies revealed that there are about one thousand people who live and interact on daily basis with the wetland. These numbers of people has a minor impact on the wetland. Accordingly, human effect has been neglected in this evaluation.

1.6.3.6 Groundwater

The behavior of the aquifer in the dune system provides an indicator of the discharge and recharge process. The recharge was estimated at 38,000 m^3 day^{-1} and the discharge from the aquifer was estimated at 14,000 m^3 day^{-1}. As a result, the net recharge is about 24,000 m^3 day^{-1}. This volume represents the life body of water that result in water flow to Lake Bardawil.

Catchment area studies revealed that water moved northward from the Quaternary aquifer to Lake Bardawil. The permeability coefficient of an average value of about 425 m day^{-1} was considered in groundwater modeling. Using an average slope of the ground surface of about 0.0025 m m^{-1} and an interface length of about 22.5 km, the groundwater aquifer contributes to the wetland an average daily volume of about 24,000 m^3. This rate contributes as much as 720,000 m^3 $month^{-1}$. This volume is considered as a constant rate of groundwater contribution each month.

1.6.3.7 Interaction between the wetland, the lake, and the Sea

To estimate the interaction between the wetland and the adjacent water bodies represented by Lake Bardawil and the Mediterranean, a water balance procedure was implemented for quantifying the hydrologic components that were important within a specified drainage system. To evaluate the change in the storage for Zaranik Wetland, the water budget was estimated as follows:

dS/dt = *Inflow – Outflow*, where: dS/dt = change of storage within the wetland over a specified time interval, Inflow = water bodies contribution to the wetland, and Outflow = water losses and water interaction with the sea. Inflow term is represented by the rainfall volume and ground water distribution, while the Outflow term is represented by the evaporation and water released from the wetland for salt production requirement (Table 1.5).

Table 1.5. **Water Balance of Zaranik Wetland. % WR = Percentage of item related to total water volume within the system (after El-Shinnawy 2002).**

Month	Rainfall (10^6 m^3)	G Water (10^6 m^3)	Salt Req. (10^6 m^3)	Evaporation (10^6 m^3)	In–Outflow (10^6 m^3)	Water depth (cm)
Jan	3.20	0.72	15.33	18.53	-29.95	-17.6
Feb	2.73	0.72	15.90	19.21	-31.66	-18.6
Mar	2.02	0.72	19.42	23.46	-40.13	-23.6
April	0.99	0.72	20.68	24.94	-43.91	-25.8
May	0.42	0.72	22.65	27.37	-48.88	-28.8
June	0.00	0.72	23.49	28.39	-51.17	-30.1
July	0.00	0.72	25.18	30.43	-54.89	-32.3
Aug	0.00	0.72	24.76	29.92	-53.96	-31.7
Sep	0.09	0.72	23.21	28.05	-50.46	-29.7
Oct	0.76	0.72	22.09	26.69	-47.30	-27.8
Nov	2.35	0.72	19.42	23.46	-39.81	-23.4
Dec	3.18	0.72	17.87	21.59	-35.56	-20.9
Total	**15.73**	**8.64**	**250.00**	**302.04**	**527.68**	
%WR	**2.85**	**1.65**	**45.29**	**54.71**	**95.60**	

Results of the water balance in Zaranik Wetland (Fig. 1.11) indicate the following: 1- rainfall represents < 3 % of the total inflow, 2- groundwater

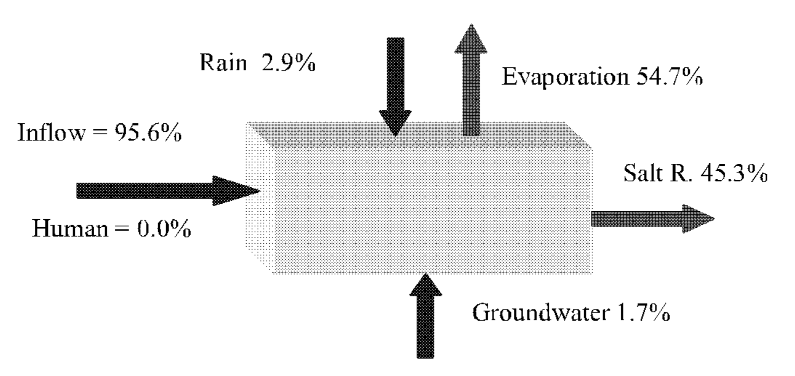


Fig. 1.11. **Water Balance of Zaranik Wetland (Shinnawy 2002).**

contribute < 2 % of the total inflow, 3- total water inflow represented by rainfall and groundwater is about 24.4 10^6 m^3 yr^{-1}, 4- evaporation losses represent about 54.7 % of the total outflow, 5- salt water requirement represents about 45.3 % of the water outflow, 6- water moves always from the sea towards the wetland, 7- water in the wetland goes below sea level with depths that range from –17.6 in January to –32.3 cm in July and 8- water movement below the sea

level is not observable (the rate is less than 1 cm day^{-1}), wave movement recovers this daily draw down.

1.7 ENVIRONMENTAL IMPACTS UPON THE BIODIVERSITY OF NORTHERN SINAI

Land degradation and desertification in the northern Sinai have been severe in the last century (Tsoar 1995, Tsoar & Karnieli 1996). The landscape and native vegetation have been significantly altered by agriculture, livestock overgrazing, wood cutting, introduction of exotic species, urbanization and its attendant effects, and military activities (El-Bana 2003).

1.7.1 Agriculture

Agriculture in northern Sinai consists (up till now, 2006) in general of rainfed cropping and ground water irrigated farming. Rainfed agriculture depends on the amount of precipitation, the additional runoff supply, and infiltration characteristics and water capacity of soils. Cultivation based on ground water has existed for a long time in Wadi El Arish area and on the coastal strip between El-Arish and Rafah. The total area of the cultivated fields has increased from about 34,000 ha in 1982 to 250,000 ha in 1998 (North Sinai Governorate). The main cultivations include grain crops, fruit trees and vegetables. Land degradation that menace rainfed and ground water farmlands has become a serious problem in many areas of northern Sinai.

An expanding threat is dryland salinity caused by rising water tables. The broad-scale clearing of deep-rooted, perennial vegetation and its replacement with shallow-rooted annual crops is the principal cause of dryland stalinization (Nulsen 1992, McFarlane *et al.* 1995). On the other hand, as farming becomes less profitable, farmers simply abandon the land to natural degradation processes without implementing long-term remediation strategies. Remnant vegetation on agricultural land is often highly fragmented, of small size, degraded by other processes such as overgrazing, and often suffers from disruption ecological processes (Hobbs 1993).

In addition to more traditional cultivation, the North Sinai Agricultural Development Project (NSADP) was started in 1992 to reclaim and irrigate 400,000 Feddan with fresh water from the Nile mixed with the reused drainage water from El-Sirw and Bahr Hadous drains, via El-Salam Canal (Fig. 2). No doubt, mixing with the drainage water would worsen the quality of canal water, particularly in terms of dissolved oxygen (DO), biological oxygen demand (BOD) and salinity. Thus, it is expected that the execution of the project will inevitably initiate major changes of the ecological character of the natural ecosystems in this area. For example, most of the industrial, domestic and agricultural run-off water draining from the eastern section of the proposed de-

velopment would flow into Lake Bardawil, an oligotrophic hypersaline desert lake of international conservation importance (Ramsar Site).

Moreover, this region is not infected by schistosomiasis at present. Improper maintenance of this canal would cause the stagnation which may result in spread of many aquatic weeds of invasive nature, and consequently malaria and schistosomiasis. Therefore, the careful water management under proper maintenance is strongly required (JICA 1989). Chemical pesticides may necessarily be used to control pests to achieve the target agricultural yield, such chemicals have a strong residual toxicity and cause damage to land and water. Thus utilization of chemicals should be minimized and a comprehensive pest control system should be introduced.

1.7.2 Desertification

The major environmental threat in northern Sinai is the problem of desertification (Tsoar 1995, Tsoar & Karnieli 1996). Like in many other regions of the Middle East, desertification in northern Sinai is closely linked to severe human landuse, mostly overcutting and overgrazing (Tsoar 1995, Batanouny 2001). Generally, desertification is manifested by three main features: 1. increase in aeolian processes such as erosion, transportation and deposition of sand; 2. reduction of vegetation cover (particularly the shrub cover); and 3. decrease in species diversity (Dregne 1983).

1.7.3 Wind Erosion

Processes of sand encroachment and mobile dunes are widespread in northern Sinai. Sand encroachment causes hazards to the cultivated areas and threatens the infrastructure, population centers, strategic installation and means of communication in most areas. These processes have adverse impacts on transportation of inputs and produced agricultural commodities, as well as on marketing processes and living habitats. According to Shata (1984) and Hereher (2000), wind erosion is a main mechanism of degradation in northern Sinai. In addition, it represents the area of most severe dune migration (>15 m year^{-1}) throughout Egypt (Mipak and El Ghazawy 1989). Soil loss by wind directly results in species losses because of the removal of resources required for establishment and survival. Wind erosion leads to nutrient removal from fertile top soil by three main mechanisms: 1- physical removal of fine particles, litter and organic matter; 2- wind suspension of dust particles with high concentrations of plant nutrients (Leys & McTainsh 1994); and 3- retarded accumulation of organic N due to increased surface and air temperatures (Post *et al.* 1985). Removal of these resources from the nutrient-limited soil of deserts limits water and nutrient availability to plants (Schlesinger & Pilmanis 1998). In addition, the wind-blown sand is very abrasive adding to the difficulties in plant establishment.

Nowadays, large areas of Sinai Mediterranean coastal lands have been planted with *Acacia saligna,* a native of Australia, to fix and stabilize the sand dunes. However, the capacity of this species to reduce erosion is limited, and individuals are found with vertically exposed roots up to 1.5 m due to wind erosion (El-Bana 2003). Furthermore, *Acacia saligna* has dramatic effects on the native vegetation and ecosystems in many Mediterranean countries (Holmes & Cowling 1997, Richardson *et al.* 1997, French & Major 2001). After an initial dormant phase it spreads exponentially: with time, all perennials and most of the annuals disappear in the vicinity of the base of its trunk (El-Bana 2003). Sterile zones of up to 16 m diameter are thus created, the restoration of which is hampered by the slow growth rates of desert plants, and by the unfavourable conditions for establishment or reproduction.

1.7.4 Rangeland Degradation

Pastoralism is one of the most widespread activities amongst North Sinai's inhabitants. In former times, many areas were far from human settlement, and there was opportunity for the natural vegetation to regenerate (Kassas 1955). Now, roads are being constructed to most villages and scenic areas thus facilitating movement of large herds between winter and summer grazing grounds and enabling access to remote plant sites. The availability of fresh (drinking) water and the prospect of the introduction of irrigation water from the Nile has encouraged the Bedouin to migrate and settle permanently in the coastal area. Therefore, the number of the herds has increased dramatically, which has prevented or slowed vegetation regeneration and contributed considerably to degraded habitats in the coastal strip. Furthermore, as new arable land is no longer available in higher rainfall zones (coastal strip between El-Arish to Rafah), crop expansion takes place into the marginal and low rainfall zones, largely encroaching into the rangelands. The consequence is that the agro-pastoral communities are grazing poorer ranges with overstocking.

Cutting trees and shrubs for fuel wood has deprived the animal population of an important source of forage of high value. As a result of overstocking, the more palatable shrubs, semi-shrubs and perennial grasses (e.g. *Panicum turgidum, Deverra tortuosa, Echiochilon fruticosum, Astragalus kahiricus* and *Artemisia monosperma*) have been replaced throughout the northern Sinai rangelands by less palatable plants (e.g. *Heliotropium digynum, Haplophyllum tuberculatum, Thymelaea hirsuta* and several spiny species) with low forage value (El-Kady & El-Shourbagy 1994). Overgrazing is thought to be a main factor responsible for the loss of some 25 plant species (El-Bana 2003), and continues to threaten some other species which are currently listed as endangered species (Boulos & Gibali 1993).

Land degradation due to overgrazing has been repeatedly identified as the main factor for albedo contrast in a satellite view between northern Sinai and western Negev (Tsoar 1995, Tsoar & Karnieli 1996). This is also demonstrated

by the difference in vegetation cover and composition between heavily grazed areas and exclosures protected from grazing. In general, throughout the northern Sinai, degradation of rangelands has reached an alarming degree, calling for prompt action. The capacity of rangelands as a feed source for livestock and for ensuring the sustainable livelihood of herders has been drastically reduced due to the combination of overgrazing and expansion of cultivation (El-Bana 2003).

1.8 SUMMARY

Northern Sinai, in which Lake Bardawil occurs, occupies about 8000 km^2, or 13% of the area of Sinai Peninsula. Lake Bardawil is mainly a flat low lying plain, bordered from the north by Sinai Mediterranean coast, from the south by a sand dune belt which extends inland to the region of fold and anticlinal hills, from the west by the Tineh Sabkha flat constituting eastern margin of the Nile Delta plain and from the east by Arish-Rafah sector. Sea water enters this lake through two artificial tidal inlets (270 and 300 m wide and 4-7 m deep); they are maintained open by periodic dredging. The third natural eastern inlet of Zaranik is now occasionally closed by silting. The bar separating the lake from the sea is arc-shaped, 300-1000 m wide. Its highest point is El-Kals (Mount Cassius), a 60 m high dune located about midway. Sediment types distribution at a benthic depth of 0-20 cm indicated that the bottom of this lagoon is sandy on the periphery, clayey sand covers most of its area, and silty clay is found in its deepest parts.

Several geomorphic and landform features produced by marine and aeolian processes occur in Bardawil lagoon. These include: shore landforms represented by foreshore slope, backshore flats, playas, sand sheets and dunes; lagoonal landforms represented by the Bardawil lagoon, islands, inlets, barrier sand flats, and sabkhas.; and aeolian landforms represented by the sand accumulation and sand dunes. Considering these landforms and the biota that inhabit them, 6 major habitat types are clearly distinguished in Lake Bardawil: Open water, salt marshes, Saline sand flats, sand hillocks, stabilized sand dunes, inter-dunes depressions, mobile sand dunes and mud flats.

The Mediterranean coastal land of Egypt belongs to the dry arid climatic zone of Koppen's classification. In general, the study area has a narrow range of variation for most of the climatic variables. The mean annual temperature varies between 20.5 °C at El Arish and 21.1 °C at Port Said. Annual evaporation rate varies between 4.5 mm day^{-1} at El Arish and 6 mm day^{-1} at Port Said. The distribution of the mean annual rainfall in Egypt shows a maximum close to the Mediterranean coast (192.1 mm $year^{-1}$ at Alexandria, 104.7 mm $year^{-1}$ at El Arish) and then decreases rapidly towards the south. The mean annual total sky cover varies between 1.6 oktas in Port Said and 2.5 oktas in El-Arish. The mean scalar wind speed varies between 4.6 knots in El-Arish and 9.0 knots in Port Said.

Results of the water balance in Zaranik Wetland indicate the following: 1- rainfall represents < 3 % of the total inflow, 2- groundwater contribute < 2 % of the total inflow, 3- total water inflow represented by rainfall and groundwater is about 24.4 10^6 m^3 yr^{-1}, 4- evaporation losses represent about 54.7 % of the total outflow, 5- salt water requirement represents about 45.3 % of the water outflow, 6- water moves always from the sea towards the wetland, 7- water in the wetland goes below sea level with depths range from –17.6 in January to –32.3 cm in July and 8- water movement below the sea level is not observable (the rate is less than 1 cm day^{-1}), wave movement recovers this daily draw down.

Land degradation and desertification in the northern Sinai have been severe in the last century. The landscape and native vegetation have been significantly altered by agriculture, livestock overgrazing, wood cutting, introduction of exotic species, urbanization and its attendant effects, and military activities.

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1.10 PLATES OF GENERAL CHARACTERISTICS

Plate 1.1

- Salt Marshes
- Salt marshes
- Parabolic-shaped sand dunes
- Camels graze on halophytes
- Crescentic transverse dunes (Barchan dunes)

Plate 1.2

- Fixing salt pans in the open water of Zaranik Protected Area.
- Fishermen's huts on an islet
- One of the sea inlets
- Fishermen
- Boats of fishermen
- Bedouins with their traditional clothing

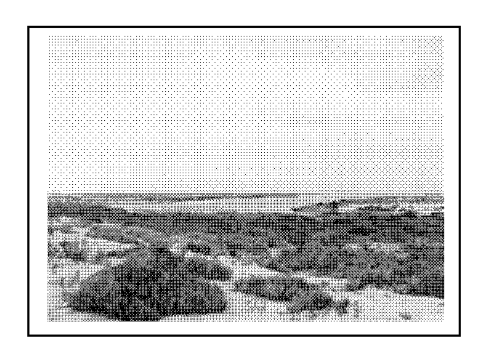
Plate 1.3

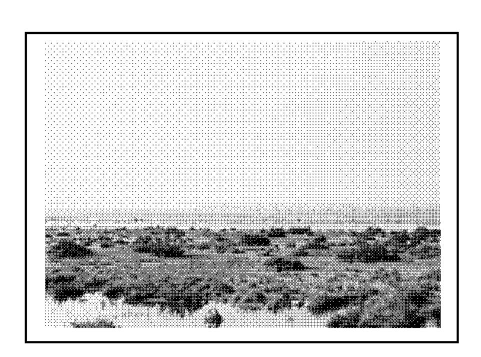
- Different views of an archaeological stone construction on Khuwaynat isllet within Lake Bardawil. Notice the unique style of masonry and the durable strength of most of the arches surrounding the central rectangular area.

Plate 1.4

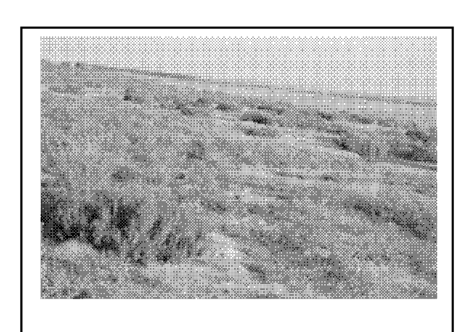
- Salt extraction by El-Nasr Salines Company from the water of Zaranik Protected Area.
- Views of the visitor center in Zaranik Protected Area.
- Dredging of the sea inlet I
- Fishermen huts close to sea inlet I

Plate 1.1

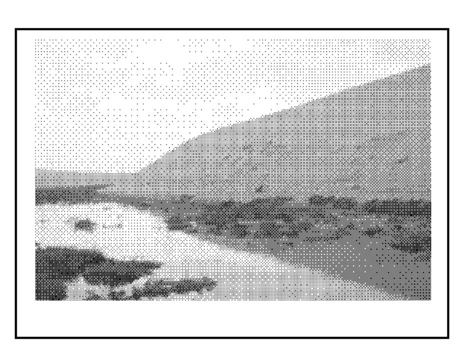




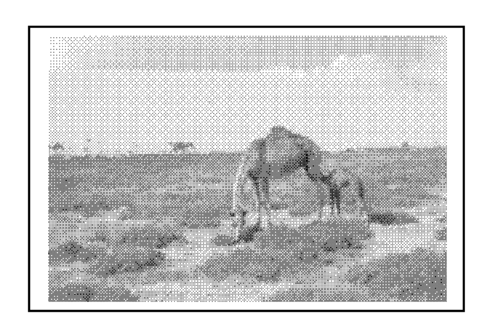
Salt marshs



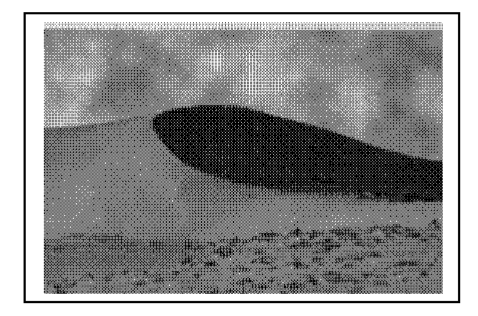
Salt marshes



Parabolic-shaped sand dunes

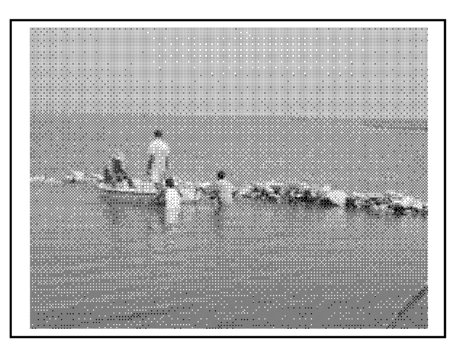


Camels graze on halophytes



Crescentic transverse dunes (Barchan dunes)

Plate 1.2



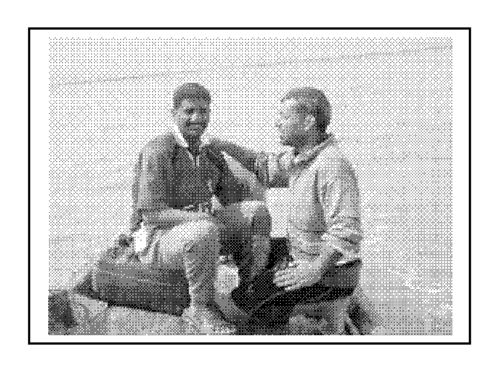
Fixing salt pans in the open water of Zaranik Protected Area.



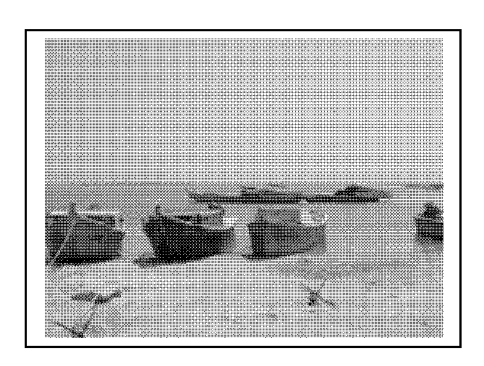
Fishermen's huts on an islet



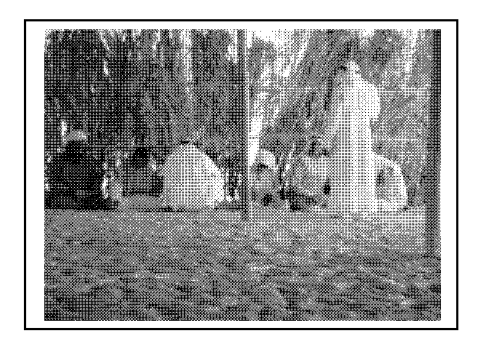
One of the sea inlets



Fishermen

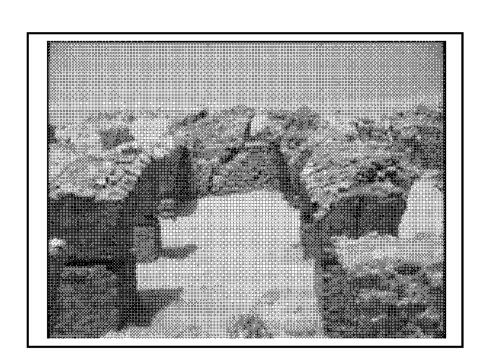


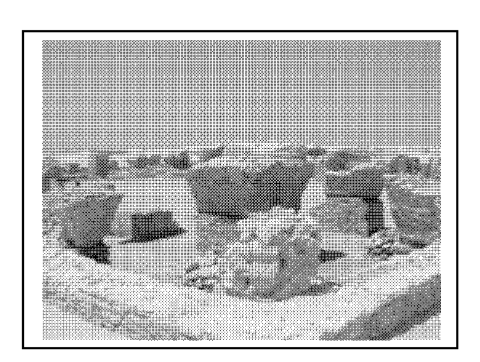
Boats of fishermen

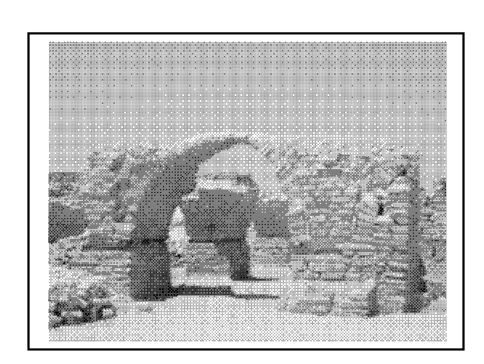


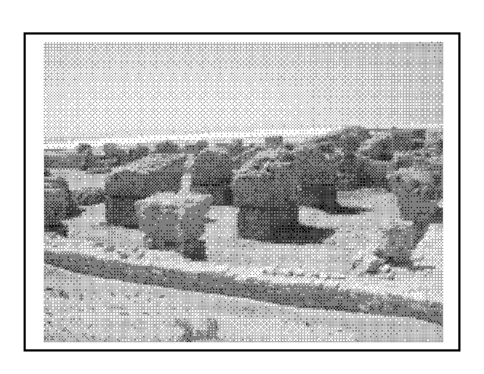
Bedouins with their traditional clothing

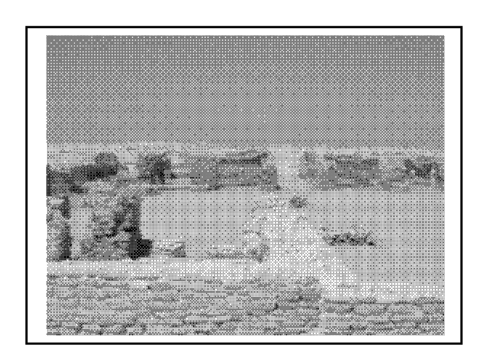
Plate 1.3

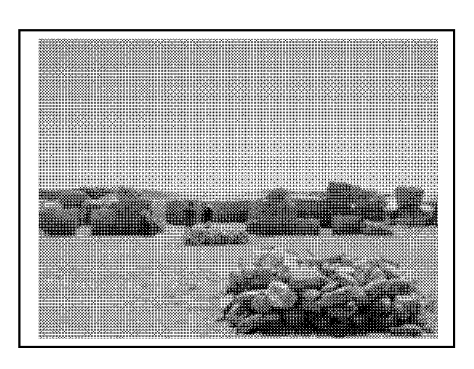






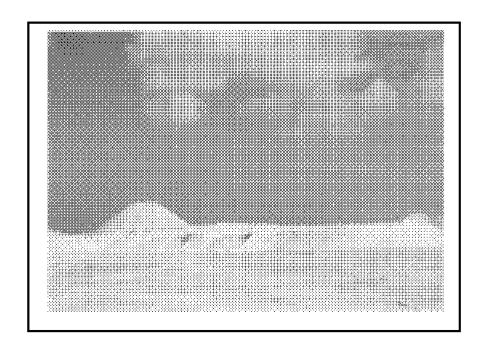


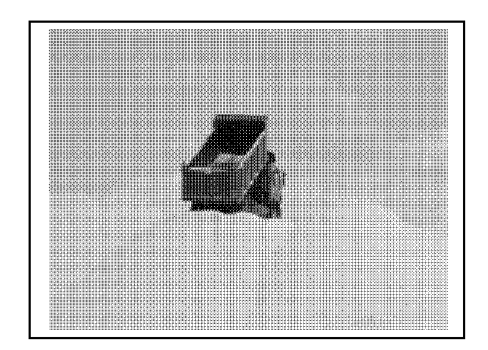




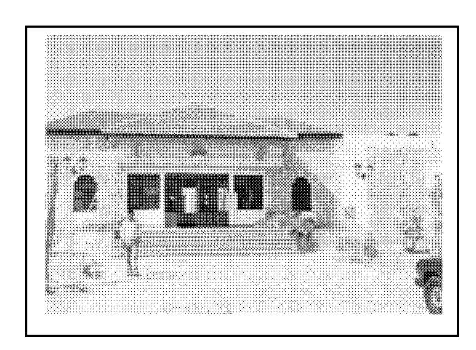
Different views of an archaeological stone construction on Khuwaynat isllet within Lake Bardawil. Notice the unique style of masonry and the durable strength of most of the arches surrounding the central rectangular area.

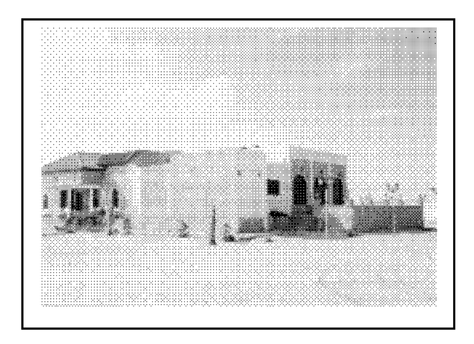
Plate 1.4



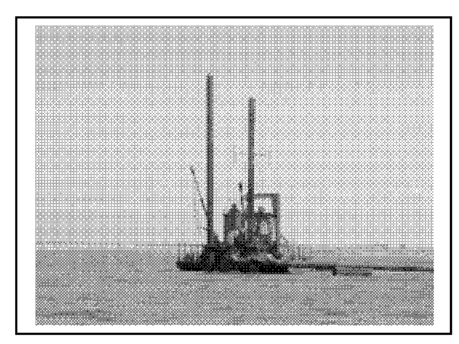


Salt extraction by El-Nasr Salines Company from the water of Zaranik Protected Area





View of the visitor center in Zaranik Protected Area.







Dredging of the sea inlet I

Fishermen huts closed to the sea inlet I

Chapter 2
Water Properties

Bardawil Lagoon is connected to the Mediterranean by a number of openings; two of them are man-made "artificial" inlets, which named "Boughaze I" at the western side and "Boughaze II" at the middle side, whilst the third one is a natural opening and located at the eastern side at El-Zaranik Protectorate Area. The two artificial inlets are opened periodically by dredging. During Israeli occupation of Sinai in 1967, both inlets were closed by 1970. Thus, the salinity of the lagoon underwent drastic increase, reached up to 70 - 90 ‰ (Pisanty 1980). The inlets were reopened from 1972 until 1978. Nowadays the most eastern lobe of Bardawil Lagoon is known as Lake Zaranik, which consists of a series of open channels between islands and mud flats and a number of man-made saltpans (Variy 1990).

2.1 CLIMATIC CONDITIONS

Bardawil Lagoon is a transitional area between the Mediterranean and the Sinai desert. High evaporation rate was recorded during July (192 mm), while the minimum value (50 mm) was recorded during December. The mean average of rainfall in Bardawil Lagoon is very modest due to its location in arid area, rainfall values fluctuated between 0 during dry months (June to October) to 20 mm during December (Table 2.1).

The increase of evaporation rate more than rainfall (precipitation) has the drastic influence, which leads to increase the water salinity of the lagoon. The net water loss calculated by Bardawil Development Project (Euroconsult 1995) from evaporation and precipitation (Table 2.1) shows a peak of net water loss of 6 mm/day in mid-summer and a minimum of 1 - 1.5 mm/day in winter.

The wind data collected by Bardawil Development Project show the predominant direction of the wind induced flows eastwards (from Boughaze I to Boughaze II). As the force of the wind acts at the surface of the water, the top layers tend to move with wind, continuity requires a return flow along the bottom.

The tidal variation of the sea level outside the lagoon forces the water to flow in and out, causing a variation of the water level inside the lagoon. The

tidal wave spreads in the lagoon with celerity of 10: 15 km/hour (Euroconsult 1995).

Table 2.1. **The climatic data and net water loss in the Bardawil Lagoon (Euroconsult 1995).**

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean temperature (^{0}C)	14	15	16	19	22	24	26	27	25	24	21	15
Rain (mm)	13	10	9	7	5	0	0	0	0	0	18	20
Evaporation rate (mm)	56	84	96	132	167	189	192	177	153	146	63	50
Net water loss (mm)	43	74	87	125	162	189	192	177	153	146	45	30
Net water loss (mm/day)	1.4	2.6	2.8	4.2	5.2	6.3	6.2	5.7	5.1	4.7	1.5	1

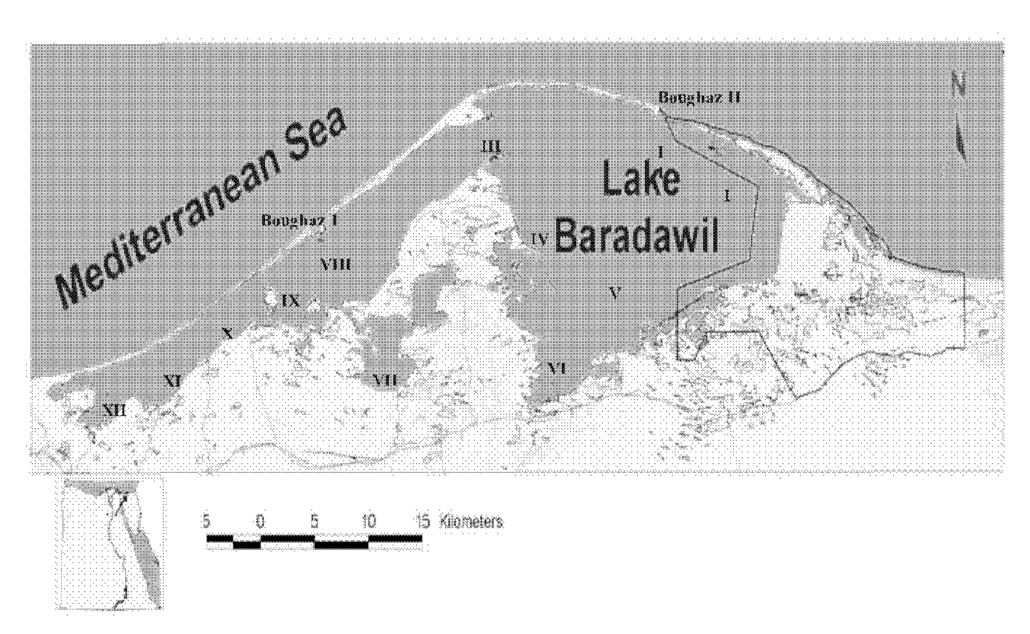


Fig. 2.1. **Map of the northern side of Sinai showing the location of the Bardawil Lagoon and the selected stations.**

2.2 WATER PROPERTIES

The water characteristics of Bardawil Lagoon were studied during 2004 (Ali *et al.* 2006), through 12 stations representing different habitats of the lagoon (Fig. 2.1). The results of their study will be discussed with other previous investigations on this lagoon.

2.2.1 Water Temperature

Temperature is a factor of great importance for aquatic ecosystem, as it affects the organisms, as well as, the chemical and physical characteristics of water. The absorption of solar radiation by Lake water influenced by an array of physical and chemical factors, and under certain condition by biotic properties of the water. These characteristics are dynamic and change seasonally and over geological time for the lake system (Wetzel 1983).

As expected, water temperature depends on latitude, altitude, mean daily number of sunshine hours and the time of collection the samples, thus the water temperature in the same month showed slight variations. The water temperatures increased in the hot months due to the increasing in air temperature and vice versa during cold months. The water temperature values fluctuated between a minimum value of 11.6 ^{0}C during January to a maximum value of 33.2 ^{0}C in July, with annual mean of 21.5 ± 6.5 ^{0}C (Table 2.2 and Fig. 2.2).

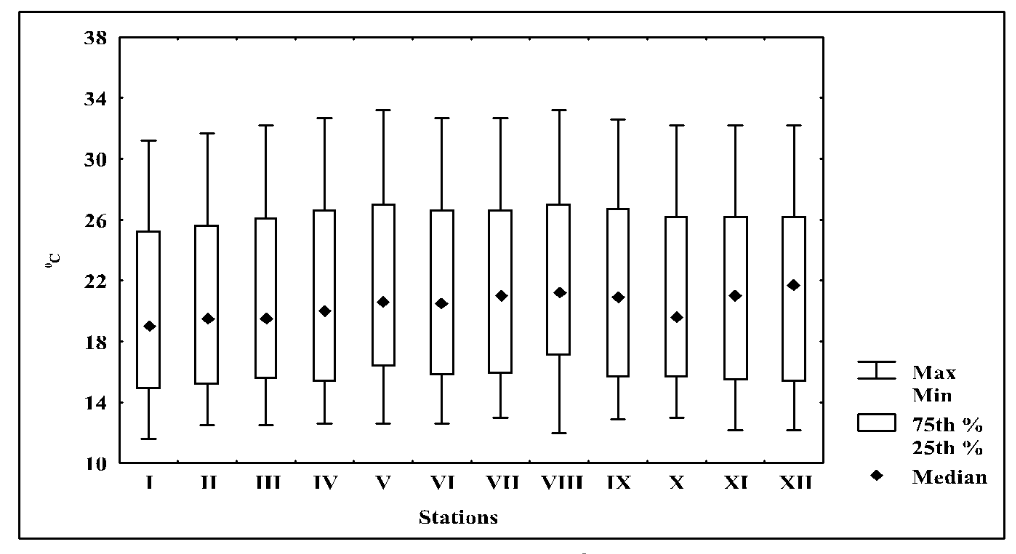


Fig. 2.2. **Monthly variation of water temperature (^{0}C) at Bardawil Lagoon during 2004.**

2.2.2 Total Dissolved Solids

Total dissolved solids (TDS) in Bardawil Lagoon showed an obvious increase during hot months as a result of high evaporation rate with low compensating by low salinity's water either through precipitation or exchange with sea water. These effects appeared in semi closed basin at station VIII (El-Rewak) and the most western station XII (Rabaa). TDS values fluctuated between a minimum value of 38.9 g/l at Boughaze II during September and a maximum value of 75.3 g/l recorded at station XII (Rabaa) during July with annual mean of 53.3 ± 2.7 g/l (Table 2.2 and Fig. 2.3).

During 1970's (Ben Tuvia 1979) pointed that, total dissolved solids exceeded 100 g/l due to the two artificial inlets were completely closed. During 1980's the value gradually decreased due to re-opening of the two inlets after Liberation of Sinai; it reached to about 90 g/l (Siliem 1989a). During 1990's Shabana (1999) and Abdel-Daiem (2000) showed that the total dissolved solids fluctuated between 40.0 - 81.5 g/l and 44 – 74 g/l, respectively.

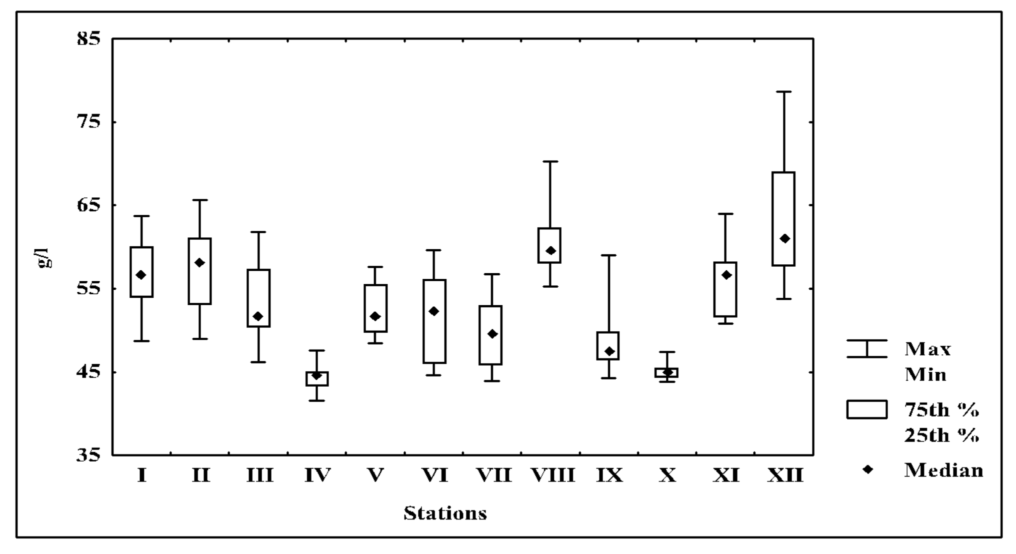


Fig. 2.3. **Monthly variation of total dissolved solids (TDS g/l) at Bardawil Lagoon during 2004.**

2.2.3 Electrical Conductivity

The values of electrical conductivity of Bardwail Lagoon fluctuated between 50.8 - 110.2 mS/cm with an annual mean of 70.7 ± 3.1 mS/cm. The obtained results revealed that, the electrical conductivity had a similar trend as total dissolved salts. However, the increase of the values during summer season was attributed mainly to the elevation of temperature and high evaporation rate (Table 2.2 and Fig. 2.4).

2.2.4 Salinity

The salinity of Bardawil Lagoon is much higher than in the open sea as a result of low rainfall (80 – 100 mm/year) and high evaporation rate (1460 mm/year). Therefore, the calculated net water loss by Euroconsult (1995) is about 2.2 million m^3 per day compensated by the inward flows through the inlets. The climatic conditions play a major role in influencing the salinity of lagoon. The salinity of lagoon shows relative variation with the distance from the two artificial openings with the Mediterranean Sea. Moreover, it shows pronounced annual changes, with the lowest salinities during winter, and the highest ones during summer.

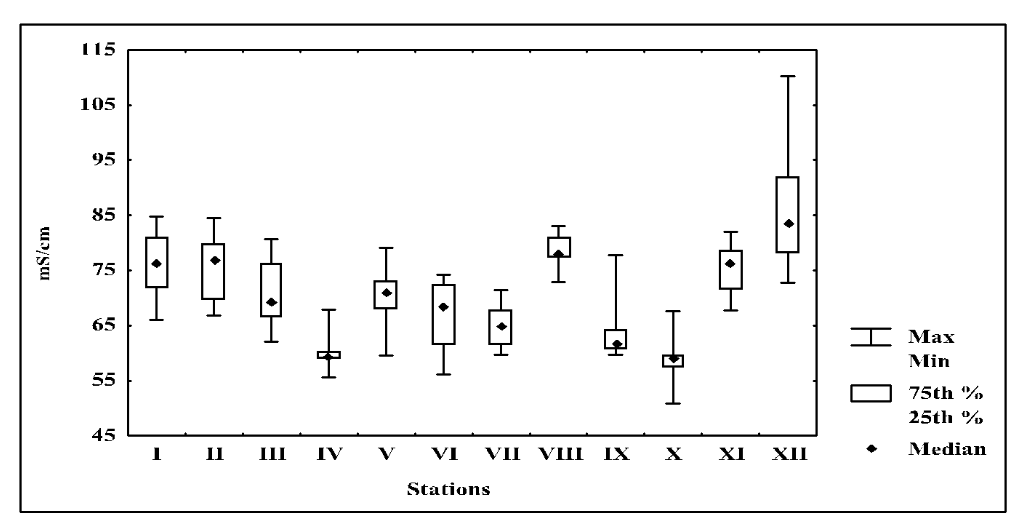


Fig. 2.4. **Monthly variation of electrical conductivity (mS/cm) at Bardawil Lagoon during 2004.**

Another additional factor influencing level of the salinity in the lagoon is the state of the openings. However, in the period of partial closure of the openings by sand the salinities are higher than after dredging. These inlets have natural tendency to be closed by sand carried along the coast by the waves and eastward coastal current at a rate of 300,000 to 500,000 m^3 per year (Euroconsult 1995). The tidal flow through the two inlets is too weak to keep them open, so continuous dredging is needed during the year to remove the accumulated sand by the General Authority for Fish Resources Development (Ministry of Agriculture).

During 1969 until 1971, the two openings were completely blocked by the accumulated sand. Consequently, the salinities of the Lagoon rose considerably reaching to about 100 ‰ and in some isolated basin the salinity reached up to 170 ‰ (Ben Tuvia 1979, Krumgalze *et al.* 1980). During 1990's the salinity values decreased gradually after dredging and re-opening of the two inlets, it reached to about 78 ‰ (Shabana 1999). The salinity values fluctuated between 54 to 68 ‰ during 2000 (Toulibah *et al.* 2002). During 2004, salinity varied between a minimum value of 38.5 ‰ during winter at Boughaze II to a maximum of 74.5 ‰ during summer at the most western part of the Lagoon with annual mean of 50.9 ± 2.9 ‰ (Table 2.2 and Fig. 2.5).

2.2.5 pH Values

Water of Bardawil Lagoon always lies in alkali side throughout the year. The minimum pH value of 7.95 was recorded at station III during October, while the maximum of 8.8 was recorded at station XI during March with annual mean value of 8.4 ± 0.2. The recorded pH levels were in agreement with those obtained by Siliem (1989a) who recorded values that ranged between 7.5 – 8.76 with annual average of 8.16. It is notable that, pH values showed slight

variation among different stations and months. However, pH values increased slightly during spring which was attributed to photosynthetic activity, which reduced the CO_2 amount in water (El-Wakeel & Whaby 1970). While the decrease of pH values during summer and early autumn may be attributed to bacterial fermentation and decomposition of organic matter (Saad 1973).

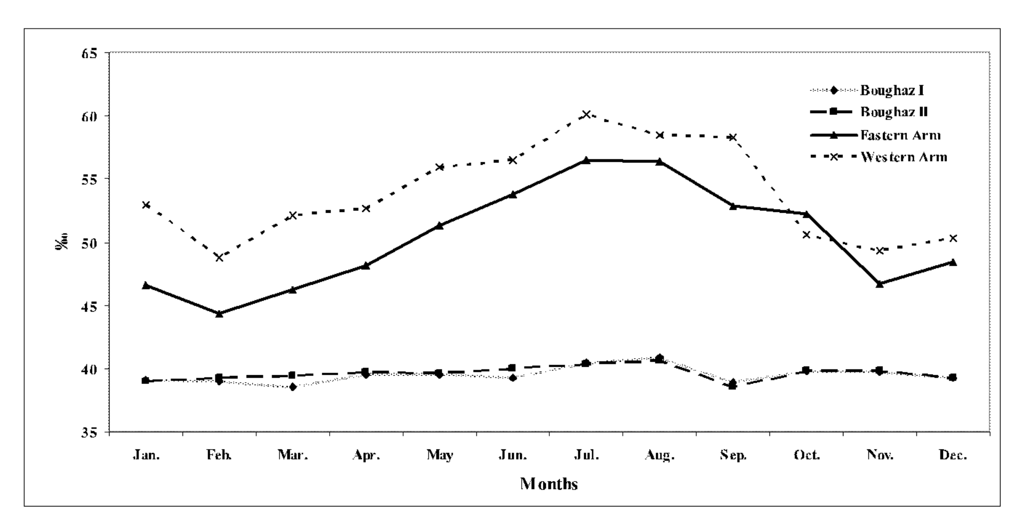


Fig. 2.5. **Average monthly variation of salinity in Bardawil Lagoon during 2004.**

2.2.6 Dissolved Oxygen

Dissolved oxygen is one of the key ecological factors. Moreover, dissolved oxygen is much more important to aquatic than to terrestrial life as oxygen has a low solubility in water and is often a limiting factor for life in water. Also, oxygen is needed for all oxidation, nitrification and decomposition processes and it is controlled by some factors: respiration, photosynthesis and exchange at the air water interface (Erez *et al.* 1990). On the other hand, oxygen is the most fundamental parameter of lakes, aside from water itself.

Water of Bardawil Lagoon is well oxygenated during different time intervals. The minimum DO value of 4.8 mg/l was recorded at station VI during July, while the maximum of 10.2 mg/l was recorded at station I during January, with annual mean value of 7.3 ± 0.9 (Table 2.3).

Dissolved oxygen values showed relative decrease during hot months, which was mainly attributed to elevation of temperature that led to decrease the solubility of oxygen (Rai 2000). In addition, the water salinity increase during summer affects adversely the solubility of oxygen (Weiss 1970). On the other hand, the increase of DO during cold months mainly attributed to decreasing of temperature and prevailing winds action which permits to increase the solubility of atmospheric oxygen (Romairo *et al.* 1979).

2.2.7 Biological Oxygen Demand (BOD)

In general, water of Bardawil Lagoon has low values of biological oxygen demand (BOD) except El-Telul area which suffered from various pollutants resulted from the tailings of fishermen at El-Telul fish-landing site (Fig. 2.6). The higher BOD values almost found in El-Telul area ranged from 2.0 to 6.5 mg/l, while the rest of the Lagoon ranged from 1.2 to 4.8 mg/l, with an annual mean value of 2.9 ± 1.0 mg/l (Table 2.3). The obtained data agreed with that reported during 2000 by Abdel-Satar (2005), who mentioned that BOD values of Bardawil Lagoon varied between 3.3 and 5.5 mg/l.

The obtained results showed that, BOD values decreased during cold months (November-February) and increased during spring months (March-May), these phenomena can be explained on the basis of abundance of bacteria, phytoplankton and other aquatic organisms.

Water of Bardawil Lagoon is nearly pure water according to the classification of Anon (1975) which pointed out that 1.0 mg/l BOD is a characteristic of pure water, while water is considered fairly pure with BOD of 3.0 mg/l and of doubtful purity when the BOD values reach 5.0 mg/l.

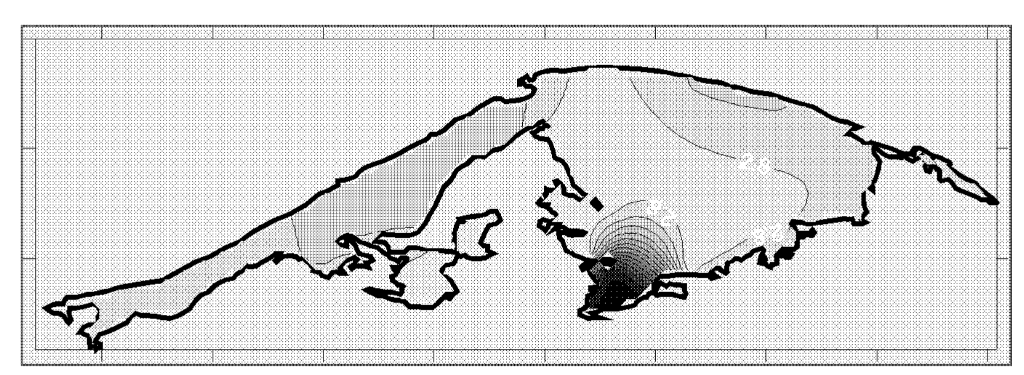


Fig. 2.6. **Annual average variation of biological oxygen demand of Bardawil Lagoon during 2004.**

2.2.8 Chemical Oxygen Demand (COD)

The values of chemical oxygen demand (COD) have a similar trend in distribution as BOD values. It increased at El-Telul area due to the tailings of fishermen at El-Telul fish-landing site which usually maintains higher values than the other sites, it ranged from 5.3 to 9.2 mg/l, while the rest of the Lagoon had a COD range of 2.1 to 8.4 mg/l, with an annual mean value of 5.2 ± 0.4 mg/l (Table 2.3 and Fig. 2.7). The obtained data is much lesser than that reported during 2000 by Abdel-Satar (2005), who mentioned that COD values of Bardawil Lagoon varied between 8.0 to 16.5 mg/l.

Water of Bardawil Lagoon is of good quality according to the classification of Beger (1942): water is considered to be a good quality when it contains not more than 12 mg/l of COD.

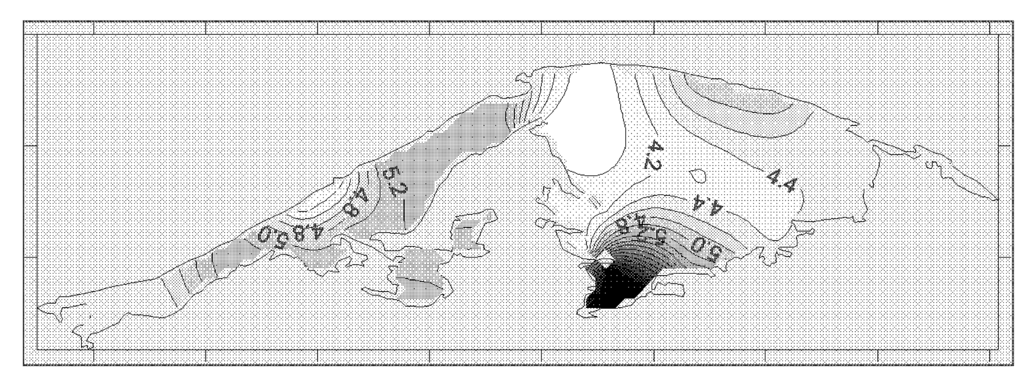


Fig. 2.7. **Average annual variation of chemical oxygen demand of Bardawil Lagoon during 2004.**

The obtained data for oxygen properties (DO, BOD and COD) showed that dissolved oxygen values were almost higher than the corresponding BOD and COD values indicating good water quality (Fig. 2.8), also the biological oxygen consumption ratios (BOC) fluctuate between 20 to 68 % with annual average of 38 ± 10.0 % giving good healthy water indication (Wetzel 1983).

On the other hand, BOD/COD ratio fluctuated between 1 : 3 and 1 : 1; this ratio concerns the biodegradability condition of an aquatic body. The ratio is in the order of 1 : 1 is characteristic of the purified water and the ratio 2 : 1 to 4 : 1 is specific to crude domestic sewage according to Anon (1975).

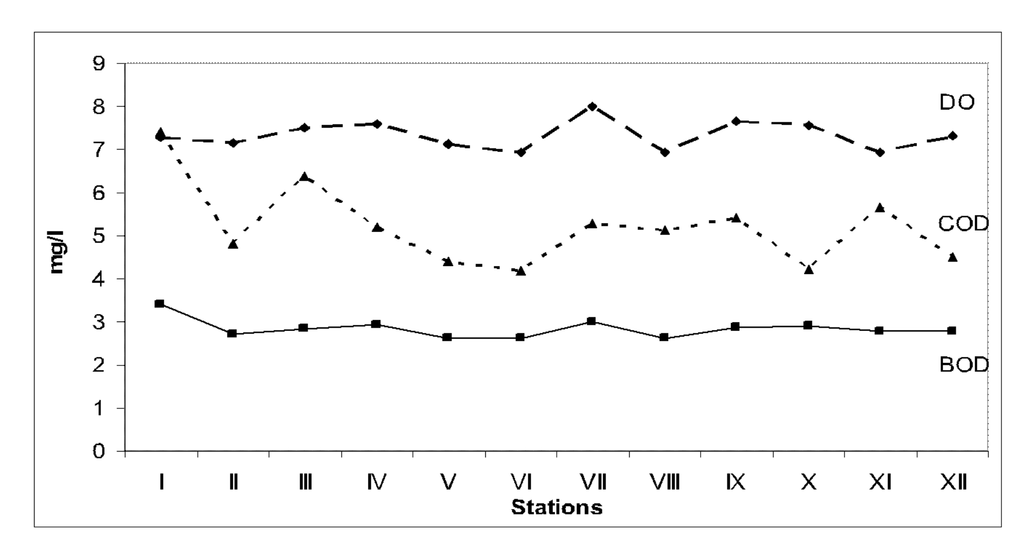


Fig. 2.8. **Average annual variation of oxygen properties (dissolved oxygen, biological oxygen demand and chemical oxygen demand) in Bardawil Lagoon during 2004.**

Table 2.2. **Range, annual mean ± standard deviation of some physical parameters (water temperature, total dissolved solids, electrical conductivity and salinity) in Bardawil Lagoon during 2004 (Amin, unpublished data).**

Parameter	W. Temp. (^0C)		TDS (g/l)		EC mS/cm		Sal. (‰)	
Station	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
I	11.6 - 31.2	20.4 ± 6.5	44.5 - 60.9	53.3 ± 5.1	66.0 - 84.8	76.1 ± 5.8	44.1 - 60.3	52.8 ± 5.0
II	12.5 - 31.7	21.6 ± 6.5	45.0 - 66.2	53.8 ± 6.2	66.8 - 84.5	76.0 ± 5.9	44.6 - 65.5	53.2 ± 6.1
III	12.5 - 32.2	21.2 ± 6.6	42.0 - 57.1	49.4 ± 5.1	62.1 - 80.7	71.1 ± 6.0	41.6 - 56.5	48.9 ± 5.0
IV	12.6 - 32.7	21.4 ± 6.9	38.9 - 41.0	40.0 ± 0.6	55.6 - 67.9	60.0 ± 3.1	38.5 - 40.6	39.6 ± 0.6
V	12.6 - 32.7	22.1 ± 6.7	43.3 - 55.2	49.0 ± 3.4	59.5 - 79.1	70.0 ± 5.3	42.9 - 54.7	48.5 ± 3.4
VI	12.6 - 32.7	21.7 ± 6.7	43.4 - 51.5	48.5 ± 3.0	56.1 - 74.2	67.0 ± 6.1	43.0 - 51.0	48.0 ± 2.9
VII	13.0 - 32.8	21.9 ± 6.6	43.4 -52.5	47.8 ± 2.8	59.7 - 71.5	64.9 ± 4.1	43.0 - 52.0	47.3 ± 2.8
VIII	12.0 - 32.2	22.2 ± 6.8	51.5 - 61.9	55.8 ± 2.8	72.8 - 83.0	78.6 ± 2.9	51.0 - 61.3	55.2 ± 2.8
IX	12.9 - 32.6	21.8 ± 6.7	39.8 - 54.0	42.9 ± 3.9	59.7 - 77.8	63.8 ± 5.5	39.4 - 53.5	42.5 ± 3.9
X	13.0 - 32.2	21.4 ± 6.4	38.9 - 41.3	39.9 ± 0.7	50.8 - 67.6	58.8 ± 3.8	38.5 - 40.9	39.5 ± 0.7
XI	12.2 - 32.2	21.5 ± 6.6	47.0 - 60.3	52.9 ± 4.3	67.8 - 82.0	75.2 ± 4.6	46.5 - 59.7	52.3 ± 4.2
XII	12.2 - 32.2	21.6 ± 6.7	49.6 - 75.3	61.1 ± 8.1	72.7 - 110.2	86.5 ± 11.1	49.1 74.5	60.5 ± 8.0
Mean	11. 6 – 32.8	21.5 ± 6.5	38.9 – 75.3	53.3 ± 2.7	50.8 – 110.2	70.7 ± 3.1	38.5 – 74.5	50.9 ± 2.9

2.2.9 Major Anions

Carbonate and bicarbonate alkalinity

Carbonate in Bardawil Lagoon is almost depleted especially during autumn and winter as a consequence of its precipitation as $CaCO_3$ onto the overlying sediment, conversion to bicarbonate according to the equation,

$$\mathbf{CO_3^{-} + H^{+} \longleftrightarrow HCO_3^{-}}$$ (Spotte 1979).

On the other hand, carbonate values increased gradually during spring and summer and reached its maximum value of 40 mg/l due to increase of the amount of dissolved carbon dioxide which converted to carbonate in the water environment according to Spotte (1979) equation:

$$\mathbf{CO_{2(g)} = CO_{2(aq)} + H_2O = H_2CO_3 = H^{+} + HCO_3^{-} = 2H^{+} + CO_3^{--}}$$

Bicarbonate is the one of the most important anion in natural water ecosystem having two important functions; first, it provides the main buffer system for resulting pH of water, second it provides the carbon dioxide necessary for the photosynthetic process of phytoplankton (Golterman 1975).

Bicarbonate values in Bardawil Lagoon showed obvious decrease during spring where the minimum value of 120 mg/l was recorded and attributed to utilization of dissolved carbon dioxide that resulted from converting calcium bicarbonate to calcium carbonate as follow:

$$\mathbf{Ca(HCO_3)_2 \Longleftrightarrow CaCO_3 + H_2O + CO_2}$$ (Aboul-Kassim 1987).

Also the values showed increasing during summer with maximum value of 220 mg/l which was attributed to high rate of evaporation that increased salt content (Table 2.4). Siliem (1988b) cited that bicarbonate alkalinity varied between 147 – 295 mg/l during 1985, while during 2000 Abdel-Satar (2005) recorded fluctuation values between 140 – 260 mg/l.

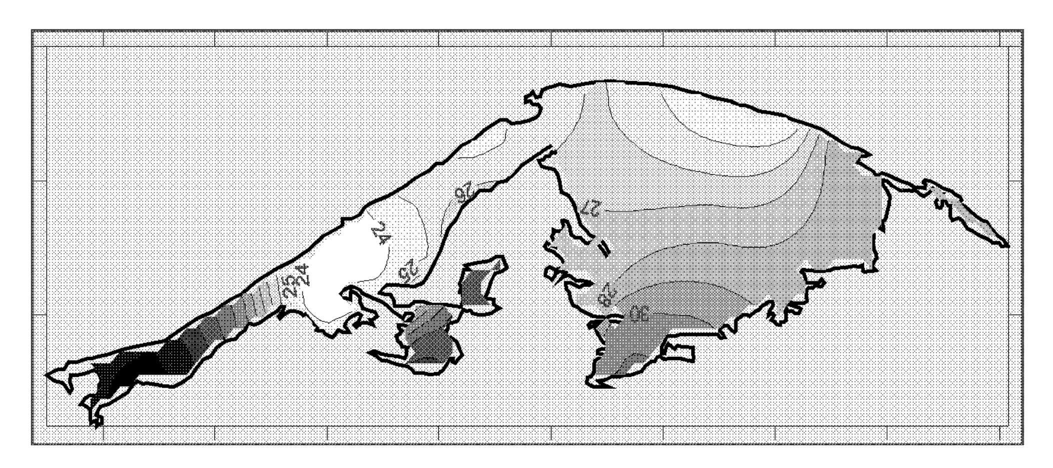


Fig. 2.9. **Average annual variation of chloride (g/l) in Bardawil Lagoon during 2004.**

Table 2.3. **Range, annual mean ± standard deviation of pH values, dissolved oxygen, biological oxygen demand and chemical oxygen demand in Bardawil Lagoon during 2004 (after Ali *et al.* 2006)**

Parameter	**pH values**		**Dissolved oxygen (mg/l)**		**Biological oxygen demand (mg/l)**		**Chemical oxygen demand (mg/l)**	
Station	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**
I	8.01 - 8.72	8.32 ± 0.21	5.0 - 9.7	7.3 ± 1.6	2.6 - 6.5	3.4 ± 1.7	5.3 - 9.2	7.4 ± 1.3
II	8.00 - 8.66	8.35 ± 0.22	5.0 - 8.9	7.2 ± 1.4	1.2 - 4.6	2.7 ± 1.1	3.4 - 6.3	4.8 ± 0.9
III	7.94 - 8.57	8.37 ± 0.19	5.7 - 9.0	7.5 ± 1.2	1.6 - 4.6	2.9 ± 1.1	3.8 - 8.0	6.4 ± 1.1
IV	8.03 - 8.50	8.30 ± 0.17	5.7 - 9.6	7.6 ± 1.2	1.9 - 4.6	2.9 ± 1.1	3.4 - 8.4	5.2 ± 1.9
V	8.02 - 8.75	8.40 ± 0.26	5.3 - 8.9	7.1 ± 1.3	1.5 - 4.6	2.6 ± 0.9	2.1 - 8.6	4.4 ± 1.6
VI	8.11 - 8.55	8.34 ± 0.16	4.8 - 9.7	6.9 ± 1.4	1.6 - 4.2	2.6 ± 0.9	3.4 - 5.5	4.2 ± 0.6
VII	8.14 - 8.58	8.39 ± 0.15	5.7 - 10.2	8.0 ± 1.4	1.6 - 4.6	3.0 ± 1.3	2.5 - 6.5	5.3 ± 1.2
VIII	8.07 - 8.40	8.22 ± 0.12	5.7 - 8.9	6.9 ± 1.1	1.5 - 4.6	2.6 ± 1.0	4.0 - 6.3	5.1 ± 0.8
IX	8.07 - 8.63	8.35 ± 0.18	5.7 - 8.9	7.6 ± 1.1	1.6 - 4.6	2.9 ± 0.9	3.4 - 8.4	5.4 ± 2.0
X	8.10 - 8.53	8.34 ± 0.14	5.7 - 8.9	7.6 ± 1.2	1.6 - 4.8	2.9 ± 1.0	3.0 - 5.5	4.2 ± 0.9
XI	8.18 - 8.80	8.45 ± 0.20	5.7 - 8.1	6.9 ± 0.9	1.5 - 4.6	2.8 ± 1.1	4.2 - 8.4	5.7 ± 1.2
XII	8.21 - 8.79	8.51 ± 0.18	5.8 - 8.9	7.3 ± 1.1	1.8 - 4.6	2.8 ± 1.0	2.8 - 7.2	4.5 ± 1.2
Mean	7.94 – 8.80	8.4 ± 0.2	4.8 – 10.2	7.3 ± 0.9	1.2 – 6.5	2.9 ± 1.0	2.1 – 9.2	5.2 ± 0.4

Chlorosity

Chloride ion is an essential element for the photosynthesis process, for photolysis of water releasing oxygen, for ATP formation and for certain phosphorylation reactions (Oser 1979).

The chlorosity of Bardawil Lagoon is governed mainly by two factors; the first is climatic condition especially the high evaporation rate, and the second is the intrusion of seawater through the inlets. So, the chlorosity increased from inlets towards southern and western areas. The minimum chloride values always recorded at Boughazes I and II area with annual average of 23.0 ± 0.8 g/l, while the highest values always recorded at the most western part of the lagoon with annual average of 35.0 ± 6.2 g/l.

The absolute minimum value of 21.0 g/l was recorded at Boughaze I, while the absolute maximum value of 46 g/l was recorded during August at the most western part of the Lagoon (Fig. 2.9).

Sulphate

Sulphur is utilized by all living organisms in both inorganic and organic forms. Sulphate is reduced to sulphhydryl {-SH} groups in protein synthesis, with a concomitant production of oxygen that is utilized in oxidative metabolic reactions. Interest in the sulphur cycle of water, however, extends beyond nutritional demands of the biota, which are met by the abundance and widespread distribution of sulphate, sulphide, and organic sulphur containing compounds. Decomposition of organic compounds containing proteinaceous sulphur and the anaerobic reduction of sulphate in waters both contribute to altered conditions that markedly affect the cycling of other nutrients, ecosystem productivity, and distribution of biota (Wetzel 1983).

The distribution pattern of sulphate showed a closely similar trend as chloride, however its values showed minimum values at Boughazes areas and the maximum values at the most western area. Sulphate values fluctuated between 2.9 – 6.6 g/l with annual average of 4.9 ± 0.5 g/l (Table 2.4 and Fig. 2.10).

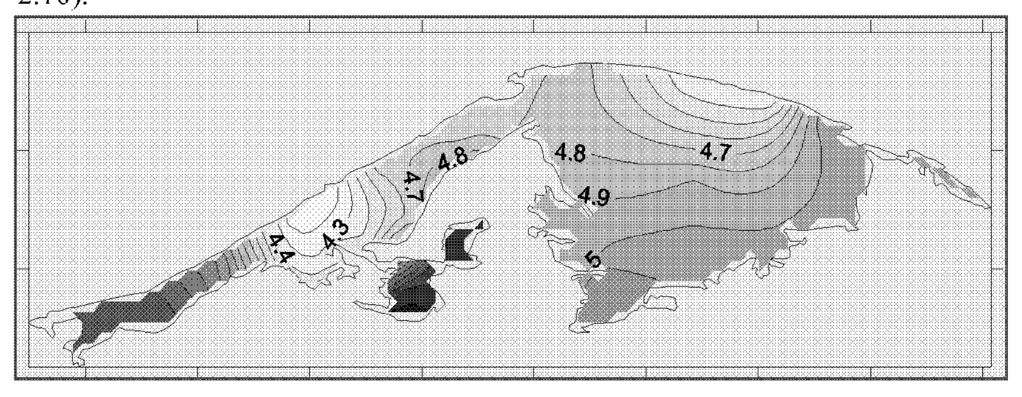


Fig. 2.10. **Average annual variation of sulphate (g/l) in Bardawil Lagoon during 2004.**

2.2.10 Major Cations

Major cations included calcium, magnesium, sodium and potassium in Bardawil Lagoon show wide variation among different months and localities. High contents were always observed during hot months (June to August) and at the inner lagoon (El-Rewak area) and at the most western part of the lagoon at Rabaa region far away the Boughaze inlets (Fig. 2.11 and Table 2.5). The main factor affecting distribution pattern of these metals is the high evaporation rate during summer, besides lesser compensating with precipitation and intrusion of seawater into the lagoon.

Calcium

Calcium contents showed wide irregular fluctuations depending on high evaporation rate and water exchange between the see and lagoon through the inlets.Calcium values in Bardawil Lagoon fluctuated between minimum value of 441 mg/l during March at Boughaze I to maximum value of 1200 mg/l during August at Station XII (Rabaa region) with annual average value of 754 ± 38 mg/l (Fig. 2.11 and Table 2.5).

Magnesium

Magnesium contents showed high values that exceed 3-5 times the calcium contents due to magnesium salts being much more soluble than their calcium counterparts. As a result, significant amounts of magnesium rarely precipitate. The carbonates of hard waters are usually > 95 % $CaCO_3$ under ordinary CO_2 pressure. $MgCO_3$ and $Mg(OH)_2$ precipitate significantly only at high pH values under most natural conditions. Consequently, the concentrations of magnesium are extremely high in closed saline basins (Wetzel & Otsuki 1974).

Minimum magnesium value (1.53 g/l) was recorded during March at Boughaze II, while the maximum value (3.11 g/l) was recorded during August at Station XII (Rabaa region) with annual average value of 2.11 ± 0.18 g/l (Table 2.5).

Magnesium distribution patterns showed a narrow range along the extent of the lagoon, which mainly was attributed to high solubility characteristics of its salts that keep a homogeneous distribution and mass balance for magnesium (Wetzel 1983). The same observation was confirmed previously by Shabana (1999) who reported that, magnesium contents in Bardawil lagoon showed homogeneous distribution pattern.

Sodium

In general, sodium predominates in water of high salinity and its concentration increases regularly with the conductivity and total ionic concentration (Talling & Talling 1965). It is derived mainly from weathering of sodium rich feldspars and to some extent clay minerals (Davis 1972). Other

Table 2.4. **Range, annual mean ± standard deviation of major anions (carbonate, bicarbonate, chloride and sulphate) in Bardawil Lagoon during 2004 (after Ali *et al.* 2006).**

Parameter	Carbonate (mg/l)		Bicarbonate (mg/l)		Chloride (g/l)		Sulphate (g/l)	
Station	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**
I	0.0 - 20	5.3 ± 6.7	144 - 197	171 ± 16.2	26 - 35	30.8 ± 2.8	4.0 - 6.3	5.2 ± 0.8
II	0.0 - 36	8.0 ± 11.7	132 - 202	174 ± 20.3	26 - 36	30.4 ± 3.0	4.2 - 5.9	5.1 ± 0.6
III	0.0 - 32	10.7 ± 12.2	132 - 197	169 ± 21.1	24 - 35	28.8 ± 3.2	3.7 - 6.0	5.0 ± 0.8
IV	0.0 - 20	3.0 ± 6.2	128 - 197	165 ± 23.3	22 - 24	24.1 ± 3.2	3.5 - 5.0	4.3 ± 0.5
V	0.0 - 36	10.3 ± 13.0	120 - 197	163 ± 25.8	25 - 32	27.5 ± 2.1	3.6 - 5.8	4.9 ± 0.7
VI	0.0 - 24	12.0 ± 11.6	142 - 216	174 ± 19.9	23 - 31	26.1 ± 2.5	4.0 - 5.8	4.7 ± 0.6
VII	0.0 - 20	6.3 ± 6.5	132 - 216	170 ± 23.8	23 - 32	25.2 ± 2.3	4.0 - 5.6	4.7 ± 0.6
VIII	0.0 - 20	5.5 ± 6.9	138 - 220	164 ± 18.0	28 - 37	32.5 ± 2.6	4.4 - 6.6	5.7 ± 0.7
IX	0.0 - 16	6.5 ± 5.5	132 - 216	166 ± 23.3	22 - 26	24.2 ± 1.2	3.7 - 5.1	4.4 ± 0.4
X	0.0 - 16	4.0 ± 6.1	140 - 211	171 ± 19.6	21 - 24	23.5 ± 2.6	2.9 - 4.8	4.1 ± 0.5
XI	0.0 - 20	10.3 ± 7.5	132 - 211	165 ± 26.2	26 - 35	30.5 ± 2.6	4.1 - 5.8	5.2 ± 0.6
XII	0.0 - 40	14.7 ± 13.9	136 - 216	173 ± 27.3	27 - 46	34.9 ± 6.2	4.2 - 6.6	5.6 ± 0.7
Mean	0.0 - 40	8.1 ± 6.4	120 - 220	169 ± 18.7	22 – 46	28.2 ± 1.9	2.9 – 6.6	4.9 ± 0.5

Table 2.5. **Range, annual mean ± standard deviation of major cations (calcium, magnesium, sodium and potassium) in Bardawil Lagoon during 2004 (after Ali *et al.* 2006).**

Parameter	Calcium (mg/l)		Magnesium (g/l)		Sodium (g/l)		Potassium (mg/l)	
Station	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**
I	601 - 962	757 ± 94	1.70 - 2.64	2.22 ± 0.24	15.0 - 19.5	16.8 ± 1.5	534 - 774	657 ± 72
II	981 - 1042	776 ± 100	1.82 - 2.57	2.24 ± 0.24	15.3 - 19.7	16.6 ± 1.5	557 - 723	638 ± 51
III	641 -1002	780 ± 139	1.72 - 2.68	2.16 ± 0.29	14.6 - 19.1	16.2 ± 1.4	460 - 808	633 ± 110
IV	481 - 641	581 ± 47	1.53 - 2.10	1.83 ± 0.20	12.1 - 18.7	14.0 ± 1.8	381 - 583	479 ± 67
V	601 - 922	753 ± 90	1.70 - 2.8	2.09 ± 0.31	13.8 - 16.4	15.1 ± 0.7	449 - 707	566 ± 78
VI	601 - 842	720 ± 106	1.70 - 2.55	1.96 ± 0.23	13.1 - 17.2	14.9 ± 1.3	494 - 664	597 ± 48
VII	561 - 721	655 ± 52	1.65 - 2.31	1.92 ± 0.22	12.9 - 17.4	14.7 ± 1.4	438 - 640	564 ± 51
VIII	984 - 1200	1047 ± 79	1.92 - 2.87	2.35 ± 0.30	15.2 - 20.5	17.9 ± 1.5	627 - 830	723 ± 63
IX	521 - 802	650 ± 97	1.72 - 2.21	1.90 ± 0.13	12.1 - 18.7	14.6 ± 1.9	404 - 573	481 ± 63
X	441 - 721	581 ± 69	1.62 - 2.01	1.81 ± 0.13	11.7 - 17.2	13.7 ± 1.6	404 - 673	503 ± 67
XI	641 - 1202	808 ± 133	2.06 - 3.02	2.29 ± 0.25	14.0 - 19.3	16.9 ± 1.5	583 - 976	676 ± 111
XII	802 - 1200	937 ± 118	1.95 - 3.11	2.53 ± 0.38	15.0 - 25.3	19.1 ± 3.3	595 - 1032	723 ± 115
Mean	441 - 1202	754 ± 38	1.53 – 3.11	2.11 ± 0.17	12.1 – 25.3	15.9 ± 0.9	381 - 1032	603 ± 39

sources of sodium in natural water include rainwater, soil leaches and atmospheric precipitation (Stangenberg-Oporowska 1967).

The values of sodium differ to a great extent according to different localities, water exchange between sea and lagoon waters and climatic conditions. The values increase during summer and gradually decrease during winter, also increase in the western part of lagoon and decrease at Boughaze areas.

The minimum value (11.7 g/l) was recorded during November at Boughaze I, while the maximum value (25.5 g/l) was recorded at Station XII (Rabba region) during August with annual average of 15.9 ± 0.9 g/l (Fig. 2.11 and Table 2.5).

Potassium

The obtained results showed slight variations in the potassium distribution pattern. Also, the little monthly variation indicate the conservative nature of this ion, which is mainly attributed to high solubility characteristics of its salts, that keeps a homogeneous distribution and mass balance for potassium (Wetzel 1983).

The values of potassium follow - to great extent – the behavior of sodium, however the climatic condition and water exchange between sea and lagoon waters play the major role in their spatial variation.

The minimum value (381 mg/l) was recorded during October at Boughaz II, while the maximum value (1032 mg/l) was recorded at Station XII (Rabba region) during August with annual average of 605 ± 37 mg/l (Fig. 2.11 and Table 2.5).

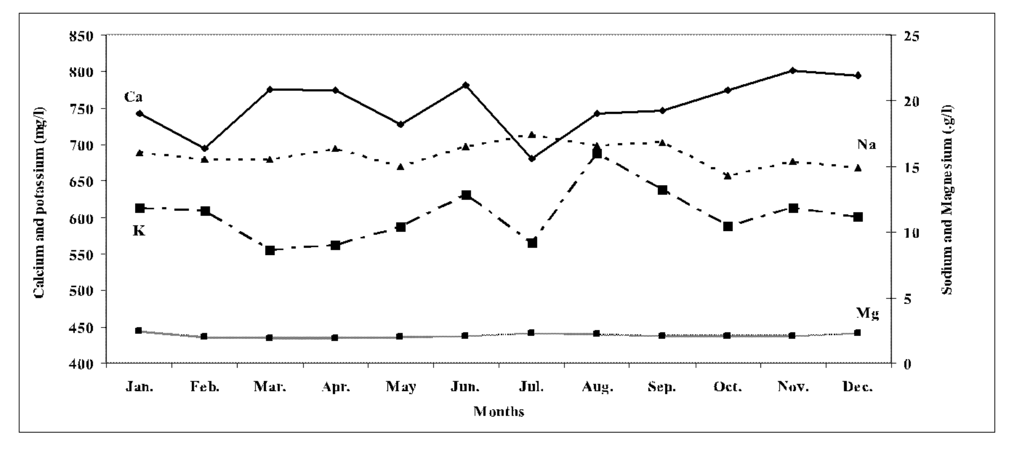


Fig. 2.11. **Average monthly variation of calcium, magnesium, sodium and potassium in Bardawil Lagoon during 2004.**

Changes in major anions and cations

In the late of 1960's and beginning of 1970's the two artificial inlets were completely closed by sand deposits. As consequence, the salinity of the lagoon underwent progressive increase and reached up to 100 ‰. As expected, major cations and anions concentrations also show progressive increase. Levy (1971) pointed out elevation of most cations and anions concentrations in Bardawil Lagoon.

Table (2.6) shows changes in concentrations of major cations in Bardawil Lagoon during different intervals in comparison with the recently (2004) obtained data. The values of major cations and anions showed gradual decrease in the recent data than that recorded by Abdel-Daiem (2000) during 1990's. Continuous dredging and digging out the two inlets play a major role in decreasing the concentration of these elements through enhancing the water exchange with the seawater.

Table 2.6. **Changes in Major Cations and Anions during different intervals**

Parameters	1985-86 (Siliem 1989)	1997 (Abdel-Daiem 2000)	2004 (Ali *et al.* 2006)
Chloride	**25.7 – 38.1 g/l**	**24 – 40 g/l**	**24 – 35 g/l**
Sulphate	**1.1 – 3.5 g/l**	**3.7 – 6.9 g/l**	**4.3 – 5.5 g/l**
Calcium	**0.8 – 1.9 g/l**	**0.62 – 1.2 g/l**	**0.67 – 1.0 g/l**
Magnesium	**1.6 – 5.3 g/l**	**1.5 – 2.9 g/l**	**1.8 – 2.5 g/l**
Sodium	**12.6 – 22.1 g/l**	**13.8 – 22.7 g/l**	**13.7 – 19.7 g/l**

2.2.11 Nutrient salts

Nutrient salts are dissolved mineral salts, the contents of which include phosphorus (P), nitrogen (N) and silica (Si). The nitrogenous salts are nitrates (NO_3), nitrites (NO_2) and ammonia (NH_4); these substances provide plants with the nitrogen they require to synthesize amino acids, which are the main components of proteins. Phosphate (PO_4) is the form in which phosphorus can be most readily used by plants to synthesize energy-rich molecules (ATP). Ninety-five per cent of the silica dissolved in the marine waters is in the form of silicic acid $Si(OH)_4$ or silicate; this substance is required by the siliceous algae such as the diatoms, as well as by the silicoflagellates and radiolarians for their development.

The availability of nutrient salts for autotrophic producers is considered as a limiting factor to productivity of any water body, while the non-available forms are considered as useless in the productivity processes. In addition, nutrients represent the fertility of the water, on which primary productivity and, ultimately, fish production depends. The amount of autotrophic producers is a function of the concentrations of the various nutrients. This relation has often

considered as the sole determinant of the dynamics of aquatic systems and persisting presence of algae in great numbers (Foy & Fistzsimons 1987).

As a whole, nutrients are regarded as limiting factors of natural water productivity, some physical condition such as light and temperature are also important.

Nitrite (NO_2-N)

Nitrogen occurs in natural waters in numerous forms: dissolved molecular N_2, a large number of organic compounds form amino acids, amines to proteins and refractory organic compounds of low nitrogen content, ammonia (NH_4^+), nitrite (NO_2^-), and Nitrate (NO_3^-). Sources of nitrogen include: (a) precipitation falling directly onto lake surface, (b) nitrogen fixation both in the water and the sediments, and (c) inputs from surface and groundwater drainage. On the other hand, loses of nitrogen occur by : (a) effluent outflow from the basin, (b) reduction of nitrate to molecular nitrogen by bacterial denitrification with subsequent return of N_2 to the atmosphere, and (c) permanent sedimentation loss of inorganic and organic nitrogen-containing compounds to the sediments (Wetzel 1983).

Nitrites depleted completely in some stations during the study periods. The annual average value of nitrite was 4.5 ± 3.3 μg/l, while the highest value of nitrite (19.2 μg/l) was recorded at station I (El-Telul region) during winter due to the pollution point at this station represented in tailings of fishermen (Table 2.7). The biological reduction of nitrite in the lagoon due to the uptake of nitrite into cellular amino acids by the photosynthesis of plankton, and by the action of transaminase enzyme, which decrease the nitrite, values in the studied area (Munawar 1970). Siliem (1989b) reported that nitrites were completely depleted during his study with some exception during winter, spring and autumn in some stations.

Nitrate (NO_3-N)

The minimum value of nitrate 13 μg/l was recorded during November at station XII, while the maximum value of 89 μg/l was recorded during January at Boughaze I area, with annual average of 42 ± 15 μg/l (Table 2.7). The obtained results of nitrate in Bardawil Lagoon showed that the nitrate concentration increased during spring and summer which was mainly attributed to the oxidation of ammonia yielding nitrate especially in abundant oxygen and phytoplankton during spring according to the following equations:

$$\mathbf{NH_4^+ + 1\tfrac{1}{2}\,O_2 \longrightarrow NO_2^- + 2H^+ + H_2O}$$

$$\mathbf{NO_2^- + \tfrac{1}{2}\,O_2 \longrightarrow NO_3^-}$$

Moreover, the nitrification processes by *Nitrosomonas* bacteria are responsible for adding nitrate to the water under control of the dissolved oxygen, this is supported by findings of Cooper (1990) and Nixon (1995). The

biological reduction of nitrate during autumn is attributed to denitrification processes by dentrifying bacterial action. However, the potential denitrification activity occurred during the period of low-water temperature (Esteves *et al.* 2001). Furthermore, the annual average values showed a noticeable increase of nitrate content westward at stations XI and XII which may be attributed to dense abundance of sea grasses in these areas (Table 2.7 and Fig. 2.12), besides an expected increase at El-Telul area as a consequence of fishermen tailings in this region.

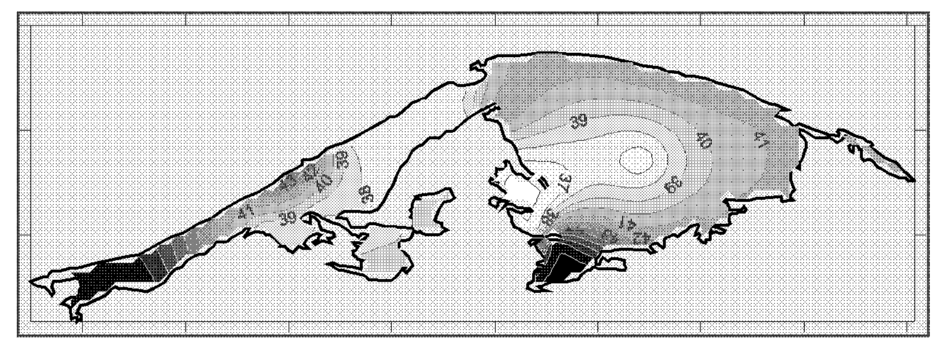


Fig. 2.12. **Average annual variation of nitrate (µg/l) in Bardawil Lagoon during 2004.**

Ammonia (NH_4^+-N)

Ammonia is generated by heterotrophic bacteria as a primary end-product of organic matter decomposition, either from proteins or from other nitrogenous organic compounds. Although ammonia is a major excretory product of aquatic animals, this nitrogen source is quantitatively a minor component compared with that generated by bacterial decomposition (Wetzel 1983). Ammonia in water is present primarily as NH_4^+ and as undissociated NH_4OH, the latter being highly toxic to many organisms, especially fish (Trussel 1972). The proportions of NH_4^+ to NH_4OH are dependent on the dissociation dynamics which are governed by pH and temperature. The approximate ratios of NH_4^+ to NH_4OH are as follows (Hutchinson 1957):

At pH = 6	3000 : 1
At pH = 7	300 : 1
At pH = 8	30 : 1
At pH = 9.5	1 : 1

With increasing the ammonium ion; ammonia equilibrium tends to shift towards ammonia (Emerson *et al.* 1975).

$$NH_4^+ + OH^- \rightleftharpoons NH_3 + H_2O$$

The maximum ammonia value of 138 µg/l was recorded at station I (El-Telul area) during September, while the minimum value of 9 µg/l was recorded

at station XI during February, with annual mean value of 48 ± 11 μg/l (Table 2.7 and Fig. 2.13).

Ammonia contents in Bardawil Lagoon showed homogeneous distribution with narrow horizontal fluctuations except station I which suffers from different pollution aspects. The regional average values showed a notable increase of ammonia concentration during summer and early autumn which was controlled by two important processes; ammonification and denitirfication as illustrated by the following equations:

Ammonification $Org\text{-}N \longrightarrow NH_4^+$

Denitrification $NO_3^- \longrightarrow NO_2^- \longrightarrow NH_3$

The two processes are not only temperature dependent, but also are dependent largely on available organic substrate (Morales *et al.* 2001).

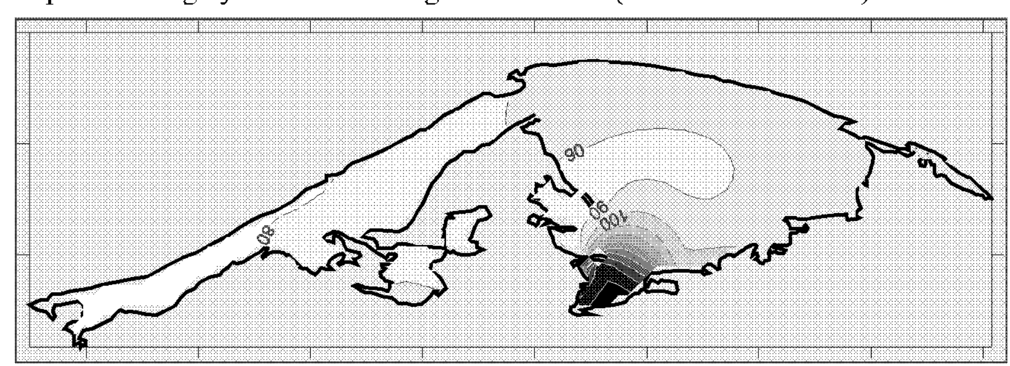


Fig. 2.13. **Average annual variation of ammonia (μg/l) in Bardawil Lagoon during 2004.**

Orthophosphate (PO_4^{-3}-P)

The cycling of phosphorus within lakes and rivers are dynamic and complex processes involving adsorption and precipitation reactions, interchange with sediments and uptake by aquatic biota (House & Casey 1989). In addition, phosphate concentration may limit the rate of photosynthesis by its effect on the utilization of phytoplankton (Goldman & Horne 1983). The orthophosphate represent the major content of dissolved phosphorus in the aquatic environment. The various inorganic phosphorus species are not well soluble and their solubility is pH dependent. Their successive dissociations are as follows:

$$H_3PO_4 \longrightarrow H^+ + H_2PO_4^- \qquad K_1 = 10^{-2.13}$$

$$H_2PO_4^- \longrightarrow H^+ + HPO_4^{--} \qquad K_2 = 10^{-7.21}$$

$$HPO_4^{--} \longrightarrow H^+ + PO_4^{-3} \qquad K_3 = 10^{-12.36}$$

$H_2PO_4^-$ and HPO_4^{--} concentrations are maximum at pH 4.67 and 9.78, respectively (Broberg & Persson 1988). The maximum orthophosphate value of 90 μg/l was recorded at station IX during April, while the minimum value of 10

μg/l was recorded at station III during December, with an annual mean value of 35 ± 12.4 μg/l (Table 2.7 and Fig. 2.14).

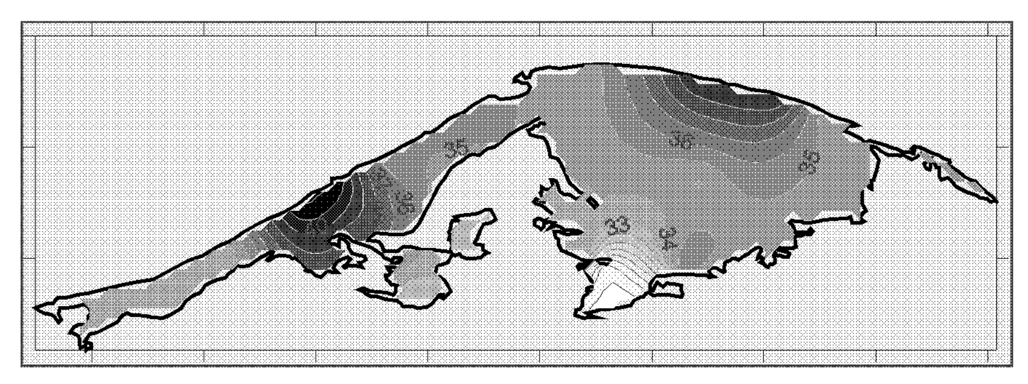


Fig. 2.14. **Average annual variation of orthophosphate (μg/l) in Bardawil Lagoon during 2004.**

The orthophosphate contents in Bardawil Lagoon showed relative increases during spring and summer comparing with the other seasons. This phenomenon attributed to decomposition of organic matter, leads to liberating phosphorus as one of the breakdown products, and the mobilization of phosphorus from sediments under microbial activities, especially in the presence of dissolved oxygen, since it plays an important role in controlling the rate of phosphate released from sediments to the photic zone (Reuter *et al.* 1998). The relative decrease of orthophosphate content during autumn, and winter attributed to its sorption on to the humic matter forming humic – iron – phosphate complexes (DHM – Fe – PO_4); this reduces the total amount of available phosphate (Jones *et al.* 1988). The regional average values showed that, Boughazes areas have the higher orthophosphate contents, it decreased gradually southward. This observation indicated that orthophosphates were transported from see water into the lagoon and consequently precipitated due to higher salinity of lagoon water than the sea water. Phosphorus forms chemically tight compounds with major cations enriched in the lagoon, these tight forms especially with magnesium (in the form of $MgPO_4$; $MgHPO_4$ and MgH_2PO_4) and calcium (in the form of $CaPO_4$; $CaHPO_4$ and CaH_2PO_4). Besides lesser values of free not-bound HPO_4 and H_2PO_4 radicals which depend on the pH variations (Pulmmer *et al.* 1984).

Reactive silicate (SiO_2 - Si)

Silicon is a non-metallic element present in the valves and cell walls of diatoms, representing 10 to 30 % of their dry weight. These diatoms are important phytoplankton group with regard to primary productivity and natural food for some fish species. The biology cycle of diatoms is closely linked to the cycling of silicon. On the whole, silicon present in water as orthosilicic acid, $Si(OH)_4$ and hydrated form of silica, SiO_2. The transformation of dissolved silicic acid into amorphous silica and backs by organisms form the core of the

Table 2.7. **Range, annual mean ± standard deviation of basic nutrient salts (nitrite, nitrate, ammonia, orthophosphate and reactive silicate) in Bardawil Lagoon during 2004 (after Ali *et al.* 2006).**

Parameter	Nitrite (µg/l)				Nitrate (µg/l)				Ammonia (µg/l)				Orthophosphate (µg/l)				Reactive silicate (mg/l)			
Station	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**
I	0.0 - 19.2	7.8	±	5.6	14 - 83	43	±	23	44 - 138	89	±	32	14 - 39	26	±	7	0.47 - 2.54	1.15	±	0.68
II	0.7 - 18.6	5.6	±	5.5	14 - 83	48	±	25	30 - 112	52	±	22	18 - 69	36	±	14	0.59 - 2.3	1.07	±	0.55
III	0.0 - 18.9	4.6	±	5.3	19 - 70	41	±	14	17 - 86	49	±	18	10 - 58	34	±	15	0.3 - 1.72	0.91	±	0.42
IV	0.0 - 14.8	4.4	±	4.0	17 - 81	42	±	21	17 - 84	47	±	19	20 - 62	40	±	15	0.51 - 2.07	0.89	±	0.42
V	0.0 - 15.6	5.3	±	5.0	19 - 57	36	±	12	18 - 65	44	±	15	12 - 65	34	±	16	0.3 - 1.83	0.87	±	0.49
VI	0.3 - 7.0	3.0	±	2.1	19 - 63	42	±	15	21 - 70	47	±	14	22 - 66	34	±	11	0.3 - 2.18	0.94	±	0.62
VII	0.6 - 14.4	4.4	±	4.4	17 - 72	38	±	20	20 - 70	44	±	14	23 - 77	35	±	14	0.39 - 2.07	0.96	±	0.57
VIII	0.0 - 12.6	4.5	±	4.6	15 - 73	39	±	18	20 - 72	45	±	15	18 - 57	33	±	11	0.47 - 3.08	1.31	±	0.81
IX	0.0 - 11.5	3.2	±	3.2	14 - 76	38	±	19	20 - 68	43	±	17	14 - 90	38	±	20	0.39 - 2.07	0.92	±	0.51
X	0.7 - 12.6	4.4	±	3.4	17 - 89	44	±	23	17 - 83	40	±	17	23 - 85	42	±	16	0.39 - 2.46	0.93	±	0.59
XI	0.0 - 13.3	3.8	±	4.2	14 - 65	42	±	22	9 - 65	37	±	18	11 - 74	34	±	17	0.3 - 1.99	0.88	±	0.55
XII	0.0 - 10.0	2.7	±	3.0	13 - 78	47	±	21	26 - 72	40	±	12	11 - 86	33	±	19	0.51 - 2.69	1.27	±	0.74
Mean	0.0 – 19.2	4.5	±	3.3	13 - 89	42	±	15	9 - 138	48	±	11	10 - 90	35	±	12	0.3 – 3.08	1.01	±	0.50

biological silicon cycle (Paasche 1980). The major source of silica is from the degradation of aluminosilicate minerals. Greatest silica concentrations are found in groundwater in contact with volcanic rocks; intermediate amounts occur in association with plutonic rocks and sediments containing feldspar and volcanic rocks fragments; and small amounts originate from marine sandstone (Schelske *et al.* 1983).

The distribution pattern of silicate in the lagoon varied in the narrow range in most cases that was attributed to the equilibrium between the deposition of silicate and production of biogenic silica from diatoms, which caused preservation in silica content distribution (Verschuren *et al.* 1998). Moreover, the uptake of dissolved silica by the aquatic microorganism especially diatoms, flagellated microalgae, macrophytes and zoobenthos causing silica preservation (Cole 1979).

The reactive silicate contents in Bardawil Lagoon increase during hot months more than the other months, that is attributed to increase of biogenic silicate (BSi) in terms of past production of diatoms (Schelske *et al.* 1983). The maximum silicate value of 3.08 mg/l was recorded at station VIII during August while the minimum value of 0.3 mg/l was recorded at stations III, VI and XI during March, with an annual mean value of 1.1 ± 0.5 mg/l.

Trophic state changes in Bardawil Lagoon

Trophic state determination is an important aspect of lake surveys. Trophic state is not the same thing as water quality, but trophic state certainly is one aspect of water quality. The concept of trophic status is based on the fact that changes in nutrient levels (measured by total phosphorus) cause changes in algal biomass (measured by chlorophyll *a*) which in turn causes changes in lake clarity (measured by Secchi disk transparency). A trophic state index is a convenient way to quantify this relationship. The most popular index was developed by Carlson (1977).

Carlson trophic state index values (TSI) calculated from Secchi disk readings, chlorophyll *a*, and total phosphorus values of Lake Bardawil are shown in Table 2.8. Moreover, it shows the trophic state values and the corresponding measurements of the three parameters. Ranges of trophic state index values are often grouped into trophic state classifications. The range between 40 and 50 is usually associated with mesotrophy (moderate productivity). Index values greater than 50 are associated with eutrophy (high productivity). Values less than 40 are associated with oligotrophy (low productivity).

The comparison of nutrient salts distribution in Bardawil Lagoon during last two decades indicated a homogeneous conservation trend (Table 2.9). The recorded values of nitrite and nitrate fluctuated in a narrow range in most studies except for Shabana (1999) who reported an obvious decrease in

concentration of both nitrite and nitrate. Ammonia concentration showed a slight increase by time, 16 – 41 µg/l recorded by Siliem (1989b), 25 – 115 µg/l recorded by Shabana (1999) and 138 µg/l during 2004 (Ali *et al.* 2006).

Table 2.8. **Trophic state gradient in temperate lake according to variation of chlorophyll-*a*, Secchi depth (SD) and total phosphorus (TP) (Carlson 1977).**

TSI	Chl. *a* (µg/L)	SD (m)	TP (µg/L)	Attributes
30-40	0.95 - 2.6	8 - 4	6 - 12	**Oligotrophy**
40-50	2.6 - 7.3	4 - 2	12 -34	**Mesotrophy**
50-80	20 - 56	0.5 - 1	48 - 96	**Eutrophy**
> 80	> 155	< 0.25	192 - 384	**Hypereutrophy**

Siliem (1989b) showed an abrupt increase of orthophosphate concentration that reached 235 µg/l, followed by obvious sharp decrease during 1997, reached 25.3 µg/l (Shabana 1999), and increased again during 2004 to 90 µg/l at El-Boughaze area, and 35 µg/l in the lagoon (Ali *et al.* 2006). Consequently, N/P ration ranged from 15: 1 to 5: 1 during 1986, decreased in the ranges of 5 : 1 to 2.5 : 1 during 2004.

Dissolved reactive silica concentrations showed obvious increase during last decade; it reached its maximum level of 3300 µg/l during 2000 (Abdel-Satar 2005) and about 3080 µg/l during 2004 (Ali *et al.* 2006).

Table 2.9. **Changes in nutrient salts (µg/l) in Bardawil Lagoon during different intervals**

Parameter	1985-86 (Siliem 1989)	1997 (Shabana 1999)	2000 (Abdel-Satar 2005)	2004 (Ali *et al.* 2006)
Nitrite	0 – 16	0.2- 4.9	2 – 21	0 - 19
Nitrate	35 – 165	2.3 – 10.1	15 – 65	13 - 89
Ammonia	16 – 41	25 – 115	*	9 - 138
Orthophosphate	3.5 – 235	0 – 25.3	3.5 – 54	10 – 90
Silicate	310 – 831	20 – 640	450 – 3300	300 - 3080

During 1960's Ben-Tuvia (1975) reported that, Bardawil Lagoon was classified as an oligotrophic lagoon with low production associated with low nitrogen and phosphorus contents. Nowadays, in the light of the recent data and according to Carlson classification, the trophic state of Bardawil Lagoon becomes mesotrophic. However, calculated TSI for the lagoon is about 50;

Seechi depth reached to 2.0 m (Abdel-Satar 2005), chlorophyll *a* concentration reached to about 0.9 µg/l (Toulibah *et al.* 2002) and phosphorus concentration about 35 µg/l (Ali *et al.* 2006).

2.2.12 Heavy Metals

Well-known examples of heavy metallic elements include iron, lead, and copper. Examples of light metals include sodium, magnesium, and potassium. Humans consume metallic elements through both water and food. Some metals such as sodium, potassium, magnesium, calcium, and iron are found in living tissue and are essential to human life-biological processes anomalies arise when they are depleted or removed. Probably less well known is that currently no less than six other heavy metals including molybdenum, manganese, cobalt, copper, and zinc, have been linked to human growth, development, achievement, and reproduction (Vahrenkamp 1979). Even these metals, however, can become toxic or undesirable when their concentrations are too great. Several heavy metals, like cadmium, lead, and mercury, are highly toxic at relatively low concentrations, can accumulate in body tissues over long periods of time.

Iron

Iron is the most abundant trace metals and serves more biological roles than any other trace metals. Iron is necessary to photosynthesizing plants. It is found in two forms; the oxidized ferric (Fe^{+3}) and the reduced ferrous (Fe^{+2}). Reducing and acidic conditions promote the solubility of iron. Most ferrous compounds are soluble in water; a noteworthy exception is FeS (Cole 1979).

The iron values in the lagoon fluctuated in narrow range with obvious increase during summer and spring more than autumn and winter. High evaporation rate during summer may be regarded as the main reason for increasing of iron, besides the elevation of temperature decreases the assimilation rate of Fe by aquatic organisms especially macrophytes (Berg *et al.* 1995). The highest value of 790 µg/l recorded during summer at station I (El-Telul area) while the minimum value of 200 µg/l recorded during autumn at station XI, with an annual mean value of 444 ± 58 µg/l (Table 2.10).

The recent data showed obvious decrease in iron value than that recorded by Abdo & Yacoob (2005) who recorded maximum iron value of 1540 µg/l at El-Telul area during summer 2000.

Manganese

The obtained results of manganese values showed increase values during hot seasons than cold seasons, which was mainly attributed to the mobilization of manganese from the sediment to the overlaying water due to the decomposition of organic debris by microbial activity (Sung & Morgan 1981). The highest value of 80 µg/l was recorded during spring at station I (El-Telul area), while the minimum value of 17 µg/l was recorded during winter at station VII, with an annual mean value of 40 ± 12 µg/l (Table 2.10).

Zinc

Zinc is essential for marine life. It is involved in various physiological mechanisms; growth, vision, sexual maturity, spawning, and various organic functions. It is known, but not elucidated, that the increased concentration of zinc makes it toxic for sensitive species (Houvet *et al.* 1989). Zinc has low human toxicity but relatively high toxicity to fish; water having up to 5 mg Zn/L, would be highly toxic to most fish species. The toxicity of zinc can be

modified by environmental factors as hardness, temperature, dissolved oxygen and presence of suspended solids or organic matter (Hodson & Sprague 1975).

The obtained results of zinc values during spring and summer 2004 showed higher values than that recorded during autumn and winter, mainly attributed to mobilization of zinc from the sediment to the overlaying water due to fermentation processes by bacterial action (Berg *et al.* 1995). The highest value of 480 μg/l was recorded during spring at station I (El-Telul area) and the minimum value of 95 μg/l was recorded during winter at station III, with an annual mean value of 166 ± 33 μg/l (Table 2.10).

Copper

Copper is a common trace constituent of natural water. Small amounts may be introduced into water by dissolution of copper and brass in water pipes and other copper-bearing equipment in contact with water, or from copper salts added to control algae in open reservoirs (Hem 1962). In soft water, copper concentrations ranging between 0.015 and 3 mgl^{-1} are toxic to many species of fish, crustaceans, molluscs, insects, zooplankton and phytoplankton (Mckee & Wolf 1963). In hard water, the concentration of copper is reduced by the precipitation of copper carbonate or other insoluble copper compounds. Increase in temperature and salinity and decrease in dissolved oxygen tend to increase the toxicity of copper to aquatic life (Alabaster & Lioyed 1980).

By contrast to results of Fe, Mn and Zn, the results of copper values showed increase during autumn and winter more than during spring and summer, which was mainly attributed to the precipitation of copper to the sediment as CuS under elevation of temperature (Hutchinson 1957). The highest value of 25 μg/l was recorded during winter at station I (El-Telul area), while the minimum value of 6 μg/l was recorded during spring at station III, with an annual mean value of 11 ± 2 μg/l (Table 2.10).

Lead

Lead is one of the most toxic elements to humans and animals, and its toxicity largely depends on its solubility. If it is present in form of $PbSO_4$, it will be more soluble than $PbCO_3$ and has greater toxicity. While in the form PbS it has very low solubility and hence lower toxicity. On the other hand, lead enters

the aquatic environment through precipitation of lead dust fallout, leaching soil and industrial wastes discharged (Clark & Micheal 1972).

The obtained results of lead showed slight increase during spring and summer more than that recorded during autumn and winter, mainly attributed to the elevation of temperature, which enhanced the mobilization of lead from the sediment, and its liberation to the overlaying water (Berg *et al.* 1995). The highest value of 53 µg/l was recorded during summer at station I (El-Telul area), while the minimum value of 9 µg/l was recorded during winter at station III, with an annual mean value of 16 ± 3 µg/l (Table 2.10).

In general, the heavy metals contents in Bardawil Lagoon show their maximal values at El-Telul area, which is the main fishery-landing site, receives the tailings of the anglers' boats, and is considered the main polluted point in the lagoon.

These values are below the standard permissible values cited by World Health Organization (WHO) and European Economic Community (EEC) (WHO 1992). The annual mean values of Fe, Mn, Zn, Cu and Pb in 2004 (444, 40, 166, 11 and 16 µg/l) are lower than the permissible limits of 500, 50, 5000, 50 and 50 µg/l for the same metals, respectively (Ali *et al.* 2006).

On the other hand, in comparison of heavy metals concentration in Bardawil Lagoon with the other lakes in Egypt, we find that the metals concentration in Bardawil Lagoon is much lower than that reported for the other lakes such as Lake Qarun, Lake Manzala and Lake Burullus (Ali & Fishar 2005).

2.2.13 Socio-Economic Impacts

The villages along the main northern road (El-Qantara – El-Arish), that lies at the southern side of the Bardawil Lagoon have been growing quickly. Most of the people live around the Bardawil Lagoon are fishermen, and others are engaged in the activities related to fisheries.

Extraction of salts by the Private Sector from the natural depressions around the Bardawil Lagoon has important economic benefits as well as impact on water quality. Reclamation of desert land around the lagoon has started, and the North Sinai Agricultural Development Project was developed for this purpose, therefore, of El-Salam Canal was constructed.

El-Salam Canal Project

1. Project summary

The North Sinai Agricultural Development Project (NSADP) as proposed and implemented by the Egyptian Government envisages the reclamation of c. 400,000 Feddan (170,000 ha) of terrain of North Sinai. The project aims at increasing agricultural production through agricultural and livestock development. The project area consists of five reclamation blocks. Block 1, the Tina Plain (60,000 Feddan) has a special character because of the heavy saline

Table 2.10. **Range, annual mean ± standard deviation of heavy metals (iron, manganese, zinc, copper and lead) in Bardawil Lagoon during 2004 (after Ali *et al.* 2006).**

Parameter	Fe (µg/l)				Mn (µg/l)				Zn (µg/l)				Cu (µg/l)				Pb (µg/l)			
Stations	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**	**Range**	**Mean**	**±**	**SD**
I	390 - 790	618	±	187	40 - 80	61	±	19	260 - 480	355	±	102	15 - 25	20	±	5	35 - 53	45	±	8
II	280 - 430	370	±	65	25 - 50	36	±	11	145 - 290	209	±	65	9 - 15	12	±	3	15 - 22	18	±	3
III	290 - 415	344	±	53	28 - 45	36	±	7	95 - 185	134	±	40	6 - 13	9	±	3	9 - 15	12	±	3
IV	295 - 510	404	±	95	25 - 66	50	±	18	135 - 185	158	±	22	9 - 15	12	±	3	10 - 15	13	±	2
V	460 - 600	540	±	63	20 - 40	30	±	9	150 - 250	198	±	44	10 - 15	12	±	2	13 - 21	17	±	4
VI	350 - 610	503	±	118	20 - 65	36	±	20	115 - 165	138	±	24	8 - 11	10	±	2	12 - 16	14	±	2
VII	540 - 650	681	±	133	17 - 55	34	±	16	95 - 135	115	±	18	7 - 12	9	±	2	10 - 18	14	±	4
VIII	590 - 640	699	±	116	28 - 55	42	±	11	100 - 140	123	±	17	8 - 11	9	±	1	10 - 14	12	±	2
IX	260 - 350	288	±	43	25 - 50	37	±	12	115 - 138	126	±	10	10 - 15	12	±	2	11 - 15	13	±	2
X	305 - 490	410	±	78	32 - 55	42	±	10	115 - 169	142	±	24	8 - 10	9	±	1	10 - 13	12	±	1
XI	200 - 310	273	±	50	26 - 65	37	±	14	115 - 200	145	±	38	8 - 15	12	±	4	11 - 17	14	±	3
XII	220 - 380	305	±	66	33 - 55	42	±	9	111 - 185	149	±	35	9 - 15	12	±	3	11 - 15	13	±	2
Mean	200 - 790	444	±	58	17 - 80	40	±	12	95 - 480	166	±	33	6 - 25	11	±	2	9 - 53	16	±	3

clay soils. Blocks 2-4 (South Qantara, Raba'a and Bir el Abd) consist of mainly deep sandy soils (totaling 205,000 Feddan). Block 5 includes a potential extension area (El Sir & Kawarir) of 135,000 Feddan consisting of loamy soils situated between 50 and 150 m ASL, which implies a high-energy demand for lifting water. No decision has been taken yet with regard to the development of the last block.

The infrastructure for the first four blocks would cater for the settlement of 21,600 families. The source of water of El-Salam Canal is River Nile at Damietta branch of the (2.1 milliard m^3) mixed with drainage water from El-Serw (430 million m^3) and Hadous drains (1.905 milliard m^3).

Water will be delivered through the El Salam Canal, which will cross under the Suez Canal by means of 1.3 km long syphon and an eastward extension of the canal of about 80 km into Sinai. Extension of the project to Block 5 may require the construction of a 30 km tunnel through an area with active dunes and of a number of pumping stations to lift the water to the potential extension area.

The project area is divided over three administrative regions: Port Said Governorate (10%), Ismailiya Governorate (20%) and North Sinai Governorate (7%).

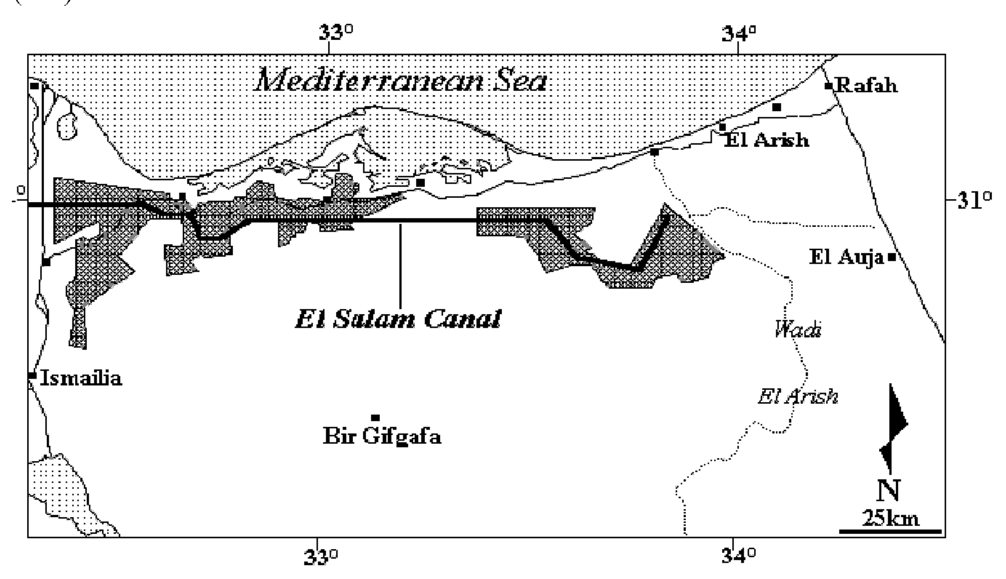


Figure 2.15. **Map of North Sinai showing the location of El Salam Canal (Euroconsult 1995).**

2- Future Threats of El-Salam Canal

a. Project Location Impacts:

1. Loss of natural habitats and increased pressure on remaining wildlands.
2. Loss of known and unknown historical and archeological sites.
3. Displacement of existing population and native land-use activities.

b. Project Design Impacts:

1. Loss of traditional land rights and loss of cultural heritage.
2. Health risks due to import of polluted irrigation water.

c. Project Operation Impacts:

1. Crop yield reduction and salinity build-up due to water shortage.
2. Increased seepage of contaminated groundwater into Bardawil Lagoon.
3. Increase in bird catching.

d. Secondary Negative Impacts:

1. Increased pressures on surrounding wildlands.
2. Negative impact on local agriculture.
3. Contamination of local wells used for drinking water.
4. Introduce of new human, animal and plant diseases to Sinai.
5. Infestation of aquatic weeds.

3- POSITIVE IMPACTS

The project is likely to generate the following positive impacts:

1. Improve socio-economic conditions.
2. Improve land tenure and land registration.
3. Development of new agro-ecological habitats; and
4. Fixation of moving sand dunes.

2.3 SUMMARY

Water temperature in Lake Bardawil during 2004 varied between 11.6 ^{0}C - 33.2 ^{0}C with an annual average value of 21.5 ± 6.5 ^{0}C. Total dissolved solids varied between 38.9 to 75.3 g/l with an annual mean of 53.3 ± 2.7 g/l. Electrical conductivity values varied between 50.8 - 110.2 mS/cm with an annual mean of 70.7 ± 3.1 mS/cm. Salinity ranged between 38.5 - 74.5 ‰ with an annual mean of 50.9 ± 2.9 ‰. It is worthy to mention that, the lowest values of TDS, EC and salinity were observed at Boughaze area, while their highest values were observed at the most western part of the lagoon.

The obtained data for oxygen properties (DO, BOD and COD) showed that DO values were almost higher than the corresponding BOD and COD values indicating good water quality. Their annual mean values were 7.3, 2.9 and 5.2 mg/l, respectively. The higher BOD and COD values almost found in El-Telul area due to fishermen tailings.

Major anions (bicarbonate, chloride and sulphate) were found in the ranges of 120 - 220 mg/l, 21.0 - 46 g/l and 2.9 – 6.6 g/l, respectively. On the

other hand, major cations (calcium, magnesium, sodium and potassium) were found in the ranges of 441 - 1200 mg/l, 1.53 – 3.11g/l, 11.7 – 25.5 and 381 - 1032 mg/l, respectively. The lowest values of major cations and anions were observed at Boughaze area, while their highest values were observed at the most western part of the lagoon.

Nutrient salts had the decreasing order of $SiO_2 > NH_4^+ > NO_3 > PO_4 > NO_2$ with annual mean values of 1100, 48, 42, 35, 4.5 µg/l, respectively. Their values were found in the ranges of 0.3 – 3.01 mg/l, 9 – 138, 13 – 89, 10 – 90 and 0.0 – 19.2 µg/l, respectively.

Heavy metals values were found in the ranges of 790 - 200, 95 - 480, 17 - 80, 9 - 53 and 6 - 25 µg/l for Fe, Zn, Mn, Pb and Cu, respectively. The annual mean values had the decreasing order of Fe > Zn > Mn > Pb > Cu with annual mean values of 444, 166, 40, 16, 11 µg/l, respectively, which are below the standard permissible values cited by World Health Organization (WHO) and European Economic Community (EEC).

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Chapter 3
Sediment Properties

Sediments are mineral or organic particles deposited by the action of wind, water, or glacial ice. These sediments can eventually form sedimentary rocks.

Classification of Sediments

Sediments are commonly subdivided into three major groups; mechanical, chemical, and organic.

1. Mechanical sediments are derived from the detritus of rocks formed earlier on the earth's surface or the bottom of oceans. Then, these are carried by streams, winds, or glaciers to the site where they are deposited. Streams deposit sediment in or carry these particles to the ocean.. Glaciers carry sediment frozen within the mass of the ice and are capable of carrying huge boulders.
2. Chemical sediments are formed by chemical reactions in water that result in the precipitation of minute mineral crystals, which settle to the floor of the water and ultimately form, more or less, chemically pure layer of sediment. For example, evaporation in shallow basins results in a sequence of evaporate sediments, which include gypsum and rock salt.
3. Organic sediments are formed as a result of plant or animal actions; for example, peat and coal beds form by the incomplete decay of vegetation and its later compaction. Deep-ocean sediment known as pelagic ooze consists largely of the remains of microscope organisms (mostly Foraminifera and diatoms) from the overlying waters as well as minor amounts of windblown volcanic and continental dust. Limestones are commonly formed by the aggregation of calcite shells of animals.

Mohamed H. Ali

The interaction between water and sediments

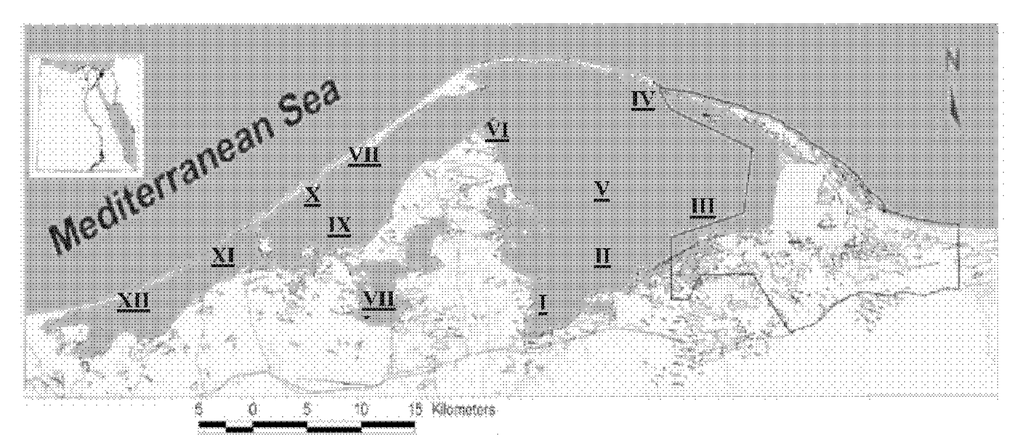
The interaction between lake water and bottom sediments takes place most actively in the shallow lakes or littoral zone. A large portion of suspended matter, carried into a lake by inflowing water, precipitates on the bottom of the littoral zone and various kinds of soluble substances are released from bottom sediments into the water. In addition, wind and wave action cause the agitation and re-suspension of fine particulate matters, either organic or inorganic, in the surface layer of bottom sediments, thereby enhancing the interaction. The quality of near-shore water thus depends on such physical properties of sediments as particle size and on their chemical content (e.g. the concentrations of nitrogen and phosphorus compounds and metal elements). These processes are obviously affected by shore geology and lake water level fluctuation, among others.

Solar radiation penetrates through the whole water column of the littoral zone and shallow water lakes, allowing submersed higher plants (macrophytes) to grow densely. The surface of submersed macrophytes as well as the bases of emerged plants offer suitable substrata for the massive growth of microorganisms such as bacteria, fungi, algae and minute animals. The resulting high biological productivity also sustains large populations of benthic animals like annelid, shellfish, insects and fish larvae. The activity of organisms, especially of microbes, in the shallow lake and littoral zones is much higher than in deep open water (pelagic zone), and causes rapid cycling of nutrients and other substances through sediment interface and over bottom water. The quality of shore water is therefore continuously changing, and the inflow from the lake's watershed adds considerably to the variability of water quality in the littoral zone. It is also widely known that soil particles play a very important role in these depositing processes and that they also trap other fine particles in water by agglutination while falling to the bottom (Wetzel 1983).

Bardawil Lagoon is a shallow water body that lies behind a sand barrier built by long-shore currents and waves. Sediments enter the lagoon by the tide and consist of materials that have been partly sorted by waves and currents. Prevailing waves have great effects in the lagoon especially near and between the two Boughazes in the north side of the lagoon. The prevailing waves from west and north cause eastward drift of the sand along the entire barrier. An estimated of the average littoral transport of sand by Delft Hydraulics during 1991 is about 500,000 m^3 in Boughaze (I) and 800,000 m^3 in Boughaze (II) (Euroconsult 1995). Moreover, erosion of the barrier supplies sand to the stream along the coast. The fine sediments carried into the lagoon by current form a great part of the bottom sediments of the lagoon, in combination with biological products like shells. The sedimentation in the lagoon is very weak, especially since the River Nile ceased to supply fine sediments into the lagoon (Euroconsult 1995).

3.1 NATURE OF SEDIMENT

The distribution of particle sizes in sediments is a function of two different processes; (1) the availability of different particle sizes in the parent material, and (2) the processes operating where the particles were deposited (Folk & Sanders 1978).



Map 3.1. **Map of the northern side of Sinai showing the location of the Bardawil Lagoon and the selected stations (Farhat 2006)**

Farhat (2006) studied the grain size of sediments in Bardawil Lagoon during 2004 at 12 stations (Map 3.1 & Table 3.1). He showed that it consists mainly of sand (72 %), mud (19 %) and very little amount of gravel size (9 %). In general, sediments of Boughaze II maintained the highest sand fractions (98.1 %), followed by low gravel percentage (1.9 %) and complete absence of mud fractions. Meanwhile, the lowest sandy fractions were found in Station V (61.2 %) with highest mud fractions (27.5 %), apparently attributed to movement of mud that resulted from dredging processes at Boughaze II. Station I (El-Telul area) has high mud fractions due to the tailings of fishermen in this area. The fermentation of these wastes leads to accumulation of organic matter and mud fractions.

The percentages of gravel, sand, and mud of the analyzed samples were plotted on triangular diagrams (Fig. 3.1) and the sediments were texturally classified according to Folk (1980).

During winter, the samples consisted mainly of gravely muddy sand (66.67%). However, few samples were gravely sandy mud (25%), and others were muddy gravelly sand (8.33%). During spring, the analyzed samples consisted of gravelly muddy sand and muddy gravelly sand (50 % for each). While in summer, the samples consisted mainly of gravelly muddy sand (75%), few samples were in the range of muddy gravelly sand (16.67%) and others were muddy sand (8.33%). During autumn, the samples consisted mainly of

gravelly muddy sand (50%) and few samples were muddy gravelly sand (33.33%), others were gravelly sand (8.33%) and sand (8.33%) (Fig. 3.1).

3.2 CHEMICAL ANALYSES

3.2.1 pH

Sediments of Bardawil lagoon mostly lie in the alkaline side except in hot months (June – August) when it lies in acidic side. This is attributed to fermentation processes of organic matter that result in liberation of methane, hydrogen sulphide in addition to the formation of organic acid and other breakdown products (Lenz 1977). The minimum pH value of 6.47 was recorded during July at station XII while the maximum value of 7.92 was recorded during December at station XI with an annual average of 7.33 ± 0.39 (Table 3.2). Ameran (2004) reported that pH values of Bardawil sediment fluctuated between 7.5 – 7.92.

3.2.2 Organic Matter

Organic matter, whether living or detritus, is generally composed of light-weight materials (El-Askary *et al.* 1988). These materials tend to accumulate in calm zones as those of fine particles. There is close relationship between the presence of fine sediments and their content of organic matter. It affects the aquatic ecosystem by interacting with inorganic matter to form complex compounds, which include several other elements. It also serves as source of food for several animal groups. Free carbon dioxide and hydrogen sulfide may be released and affect the composition of the sediments (Beltagy & Moussa 1984).

The distribution of organic matter content in the recent sediments of Bardawil Lagoon has a uniform distribution – to a great extent- with the clay distribution, the relatively high contents of organic matter in the sediments are often accompanied with high clay contents.

The organic matter content fluctuated between minimum value (0.9 %) recorded at Boughaze II and maximum one (13.3 %) recorded at El-Telul area with annual average value of 4.5 ± 0.06 % (Table 3.2). The tidal movement plays an important role in the two Boughazes since it pushes the deposited particles into the lagoon, and they maintain the lowest organic matter contents. On the other hand, El-Telul area usually has the highest value due to the fishermen's tailings.

The organic matter content fluctuated between minimum value (0.9 %) recorded at Boughaze II and maximum one (13.3 %) recorded at El-Telul area with annual average value of 4.5 ± 0.06 % (Table 3.2). The tidal movement plays an important role in the two Boughazes since it pushes the deposited particles into the lagoon, and they maintain the lowest organic matter contents. On the other hand, El-Telul area usually has the highest value due to the fishermen's tailings. This was also documented by Abdo (2005) during 2000,

who reported that organic matter content in Bardawil Lagoon fluctuated between 0.7 – 11.6 %.

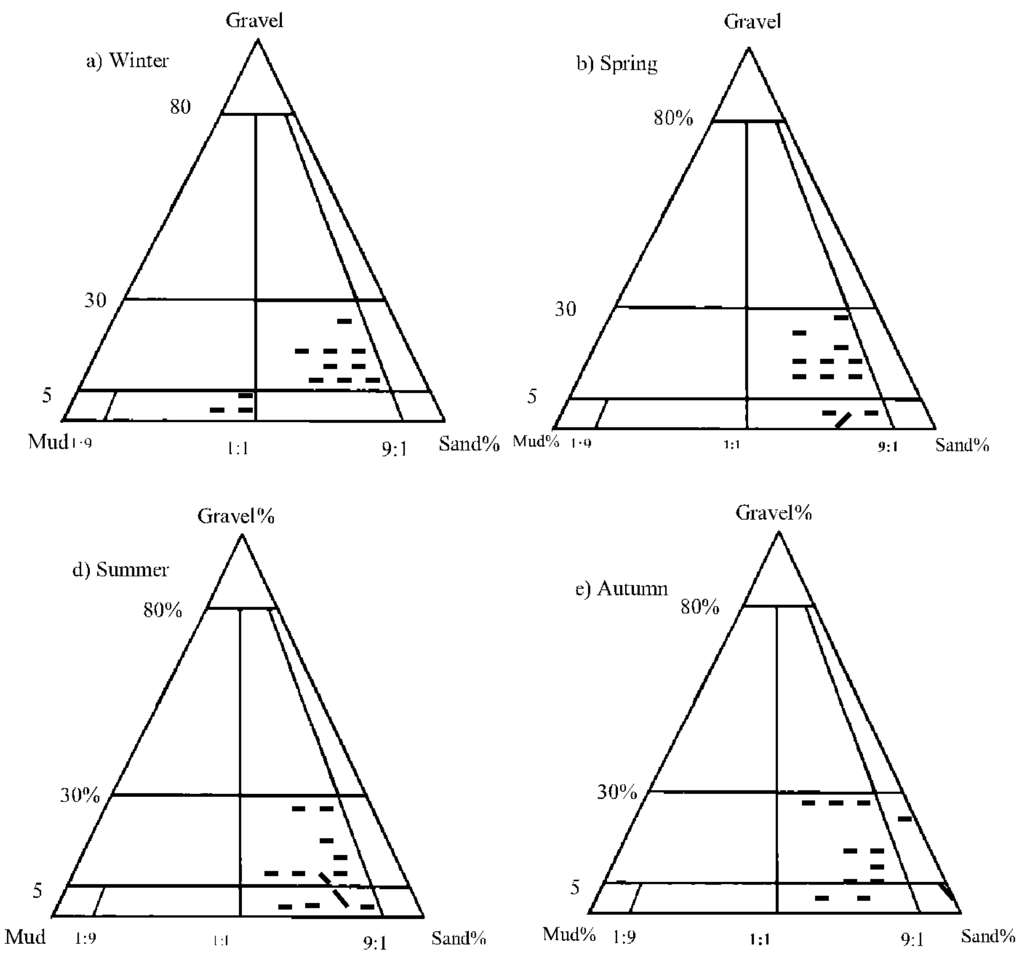


Fig. 3.1. **Sediment types of the reconstructed sedimentary units of samples from Bardawil Lagoon during (a) winter , (b) spring, (c) summer and (d) autumn 2004, according to Folk (1968) and Farhat (2006).**

3.2.3 Carbonates

Carbonates are concentrated in tropical or subtropical sediments where carbonate secreting animals are dominant. The restricted lagoon environment and the arid climate lead to the formation of coastal *sabkhat*. Two kinds of brines are found in these *sabkhat*; the first is normal marine brine resulting from evaporation of seawater, and the second is calcium chloride brine which results from the interaction of normal marine brines with pre-existing calcium carbonate minerals thus leading to the formation of digenetic dolomite (Levy 1977a & b).

Table 3.1. **Annual average of sediment fractions (%) in the sediment samples of Bardawil Lagoon during 2004 (Farhat 2006)**

Station	Gravel (> 2 mm)	Sand (1 - 0.063 mm)					Mud (< 0.063 mm)					Sediment Type
		V.C.sand	C.sand	M.sand	F.sand	V.F.sand	C.silt	M.silt	F.silt	V.F.silt	Clay	
I	6.47	4.25	2.38	17.33	32.03	10.85	12.61	6.55	3.49	1.23	2.79	Gravelly Muddy Sand
II	9.70	4.89	3.88	19.01	48.14	4.81	4.38	2.75	0.97	0.73	1.25	Gravelly Muddy Sand
III	14.02	7.37	3.57	12.55	29.45	9.25	12.88	5.51	2.38	0.57	2.46	Gravelly Sandy Mud
IV	1.56	2.64	9.28	54.50	28.56	3.14	-	-	-	-	-	Gravelly Sand
V	11.35	8.69	4.84	14.70	25.45	7.56	10.58	7.20	5.50	1.43	2.72	Gravelly Muddy Sand
VI	6.46	6.87	5.95	22.03	31.92	7.70	8.02	4.77	4.04	1.06	1.22	Gravelly Muddy Sand
VII	7.04	2.67	2.43	31.62	24.12	6.17	7.67	10.21	4.92	1.45	1.69	Gravelly Sandy Mud
VIII	11.71	6.01	4.94	17.56	34.96	7.04	6.35	2.95	5.01	2.89	1.04	Gravelly Muddy Sand
IX	11.96	4.06	2.30	19.14	38.80	6.13	6.24	4.54	4.23	1.95	0.93	Gravelly Sandy Mud
X	9.45	3.91	5.86	48.11	25.43	0.52	2.24	2.59	1.35	0.23	0.15	Muddy Gravelly Sand
XI	12.03	6.27	4.20	20.37	27.10	8.37	12.49	4.63	1.60	1.05	1.90	Gravelly Muddy Sand
XII	6.89	6.42	4.35	18.00	35.98	7.33	12.04	4.69	1.51	0.76	2.02	Gravelly Muddy Sand

The carbonate contents varied between a minimum value that was recorded at Boughaze I during winter (4.0 %) and a maximum recorded at station II during autumn (37.9 %), with annual average of 22.8 ± 0.6 % (Table 3.2).

The eastern area of Bardawil Lagoon is richer than the western one in carbonate content that mainly attributed to apparently abundance of molluscan shells. This was also documented by Lotfy (2003 a, b & c) during his study in 2000.

The Boughazes maintain the minimum carbonate contents, which is attributed to the tidal movements that cause the sediment to be washed through drift molluscan shells towards the seabed.

Table 3.2. **Range, mean and standard deviation of monthly variation of pH values, organic matter and carbonate percentage in sediment of Bardawil Lagoon during 2004 (Abdel-Karim *et al.* 2006).**

Station	pH				OM %				CO_3 %			
	Range	Mean	±	SD	Range	Mean	±	SD	Range	Mean	±	SD
I	6.68 - 7.85	7.32	±	0.36	11.0 - 15.8	13.3	±	2.0	19.0 - 24.8	21.52	±	2.4
II	6.70 - 7.79	7.31	±	0.41	4.1 - 5.6	4.7	±	0.7	28.9 - 37.9	33.17	±	4.0
III	6.50 - 7.70	7.30	±	0.44	5.0 - 6.6	5.8	±	0.8	30.5 - 35.6	32.97	±	2.1
IV	6.62 - 7.65	7.29	±	0.36	0.9 - 2.1	1.4	±	0.5	4.8 - 6.5	5.45	±	0.7
V	6.70 - 7.88	7.35	±	0.42	3.9 - 5.7	4.6	±	0.8	25.0 - 30.0	28.00	±	2.2
VI	6.66 - 7.70	7.33	±	0.36	3.9 - 4.8	4.2	±	0.4	19.1 - 25.0	21.53	±	2.6
VII	6.55 - 7.72	7.35	±	0.42	2.8 - 5.3	3.9	±	1.0	18.0 - 23.0	20.25	±	2.6
VIII	6.47 - 7.56	7.22	±	0.36	2.8 - 4.3	3.4	±	0.7	20.5 - 28.0	24.13	±	3.2
IX	6.50 - 7.77	7.30	±	0.43	1.5 - 3.0	2.1	±	0.7	22.0 - 27.0	25.25	±	2.2
X	6.59 - 7.68	7.31	±	0.41	1.1 - 1.4	1.3	±	0.1	4.0 - 6.4	5.10	±	1.1
XI	6.70 - 7.92	7.40	±	0.40	4.2 - 5.6	4.9	±	0.7	26.0 - 28	26.75	±	1.0
XII	6.70 - 7.91	7.44	±	0.43	3.6 - 5.1	4.3	±	0.7	27.0 - 33.3	29.58	±	2.8
Mean	6.47 - 7.92	7.33	±	0.39	1.1 – 15.8	4.5	±	0.06	4.0 – 37.9	22.81	±	0.6

3.3 NUTRIENT SALTS

Owing to the decomposition of organic matter by metabolic activities of microbes and benthic animals, water that fills the space between sediment particles (interstitial water) contains nutrients (HH_4-N, NO_3-N, PO_4-P etc.) at higher concentrations than in free lake water. The concentrations of nutrients in interstitial water are usually higher in sediment surface than in deeper layers, and nutrients are released upwards into lake water by diffusion even under calm conditions. Strong winds agitate sediment particles in shallow waters, resulting in more efficient release of nutrients from sediments.

Under aerobic conditions, which normally prevail in the shallow bottom of near shore zone, nitrogen compounds such as ammonia are readily released from sediments by diffusion, while the release of reactive (available for plants) forms of phosphate are very limited. Through deoxidizing reactions, phosphate and metals (including toxic heavy metals) which have remained insoluble under

aerobic conditions turn into soluble forms and are released from the bottom of the lake. Anoxic conditions also provoke denitrification or the reduction of nitrate into nitrite and N_2 and the production of sulphide from sulphates and methane from carbohydrates (Kurata & Kira 1990).

Nitrite (NO_2-N)

The available NO_2-N concentrations often recorded the least values among the nitrogenous compounds in the lagoon's sediment. The minimum value (0.06μg/g) was recorded at station VIII during November, while the maximum value (1.54μg/g) was recorded during February at station VII (Table 3.3). The distribution pattern of annual average showed irregular variation among the stations. However, the values tend to increase in the middle sector of the lagoon with the increase of muddy type sediments and decrease at two Boughazes areas with sandy sediments (Fig. 3.2). This was reported by Boey (1997) who mentioned that, clayey sediments are rich in nitrogenous compounds, while the sandy sediments are nutrient poor. An obvious increase of nitrite values was observed during late spring and summer seasons; values generally decreased during cold months (Fig. 3.3). This may be attributed mainly to decomposition of organic matter under elevation of temperature and dissolved oxygen reduction (Boynton *et al.* 1997).

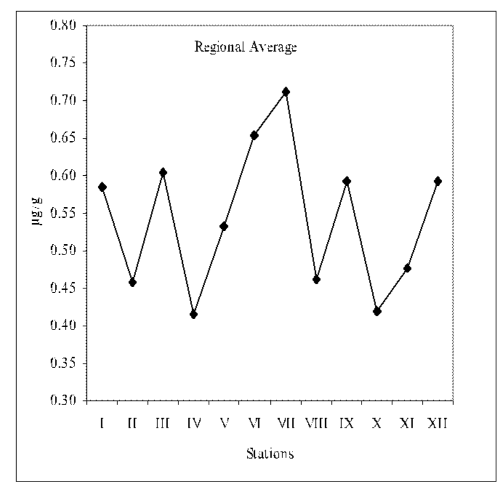
Nitrate (NO_3-N)

The exchangeable NO_3-N contents in the lagoon sediment showed moderate values ranged between a minimum value (0.8 μg/g) that was recorded at station IX during December, and a maximum value (5.59 μg/g) that was recorded during August at Boughaze I, with annual average of 3.0 ± 0.68 μg/g (Table 3.3).

Compared with nitrite, nitrate values showed opposite distribution pattern. Whereas, the two Boughazes showed higher nitrate values (Fig. 3.4). On the other hand, the nitrate values showed an obvious increase during summer and autumn and decrease during winter and spring (Fig. 3.5). This indicates the oxidized conditions of lagoon sediment, where both NO_2 and NH_4 are oxidized to nitrate (nitrification). Thus, the formed nitrate can either be released to overlying waters or remain confined in the sediments (Liikanen *et al.* 2002).

Ammonia (NH_4-N)

The dominant nitrogenous form in the lagoon sediment is ammonia. It fluctuated between a minimum value of 7.43 μg/g at Boughaze II in March and a maximum value of 327.9 μg/g at station I (El-Telul area) in January, with an annual average of 108.0 ± 33.6 μg/g (Table 3.3). On the other hand, station I (El-Telul area) showed usually higher ammonia values more than the other sites, attributed to abundance of organic matter and muddy clayey sediment type at this station as a result of fishermen tailings.



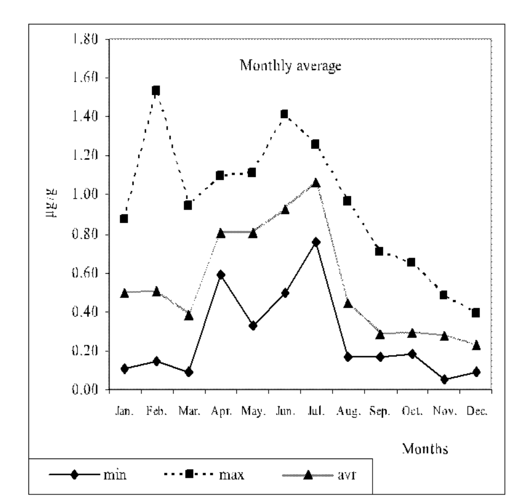


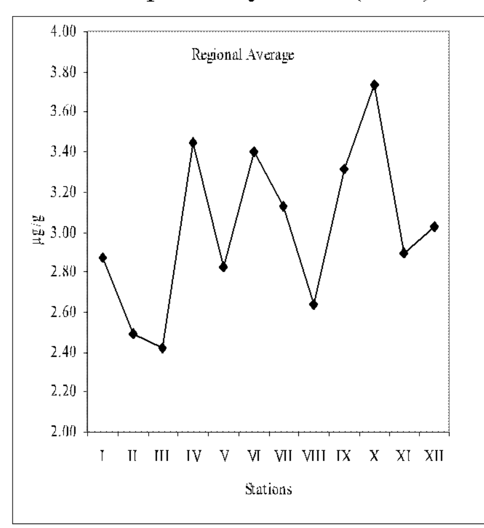


Fig. 3.2. **Regional variations of nitrite in the sediments of Bardawil Lagoon during 2004.**

Fig. 3.3 **Maximum, minimum and monthly average variations of nitrite in the sediments of Bardawil Lagoon during 2004.**

Although, ammonia contents in the Bardawil sediment may deserve more priority attention than other nitrogenous forms, but it is not a serious concern because ammonia is a non-persistent and non-cumulative toxic substance. Therefore, the high levels of ammonia in the sediment are not a great problem at present, because of higher dissolved oxygen contents and normal pH values that control the toxicity of ammonia (Johnston & Minnaard 2003).

The two artificial openings (Boughazes) showed to some extent the lowest ammonia values (Fig. 3.6) associated with high nitrate values. This could be due to that the nitrification process is enhanced by high nitrifying bacterial count as reported by Sabae (2006).



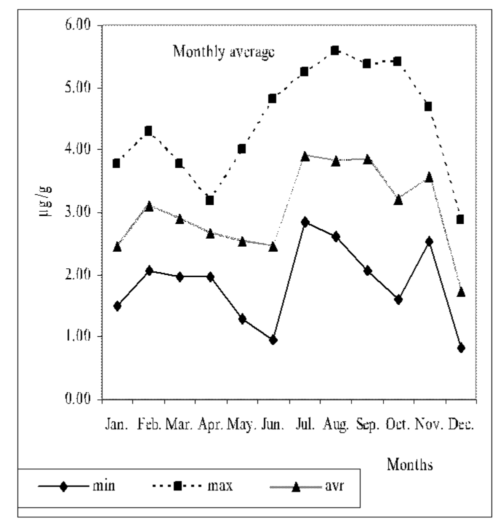


Fig. 3.4. **Regional variations of nitrate in the sediments of Bardawil Lagoon during 2004.**

Fig. 3.5. **Maximum, minimum and monthly average variations of nitrate in the sediments of Bardawil Lagoon during 2004.**

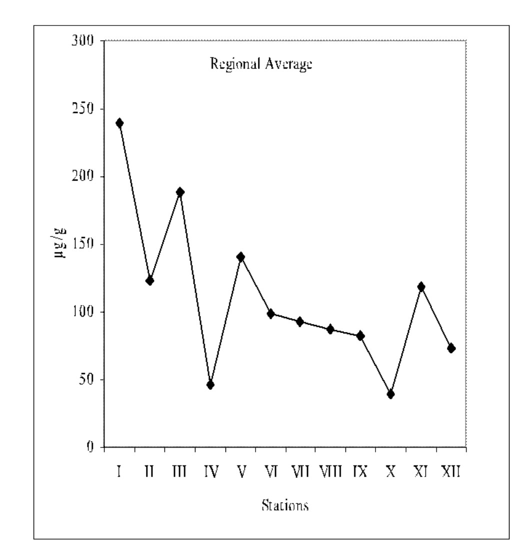


Fig. 3.6. **Regional variations of ammonia in the sediments of Bardawil lagoon during 2004.**

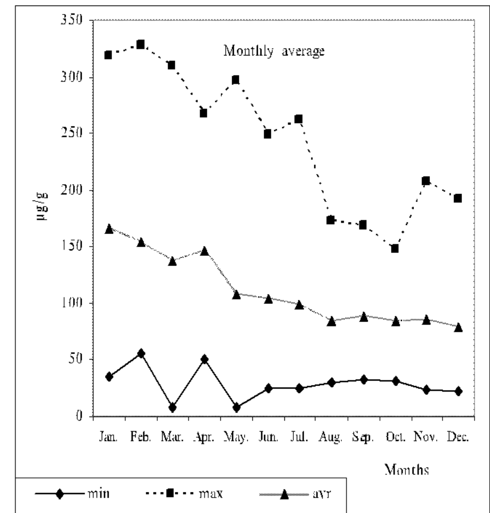


Fig. 3.7. **Maximum, minimum and monthly average variations of ammonia in the sediments of Bardawil Lagoon during 2004.**

Orthophosphate (PO_4-P)

Orthophosphate ion is highly particle-reactive and thus the sorption properties of sediment are crucial for P-retention capacity. Aerobic conditions are known to promote phosphorus sorption, while anoxic conditions favour phosphorus release (Khoshmanesh *et al.* 2002).

The orthophosphate varied between a minimum value of 1.45 µg/g at station VIII in May, and a maximum one of 9.5 µg/g at Boughaze II in October, with annual average of 4.01 ± 0.09 µg/g (Table 3.3).

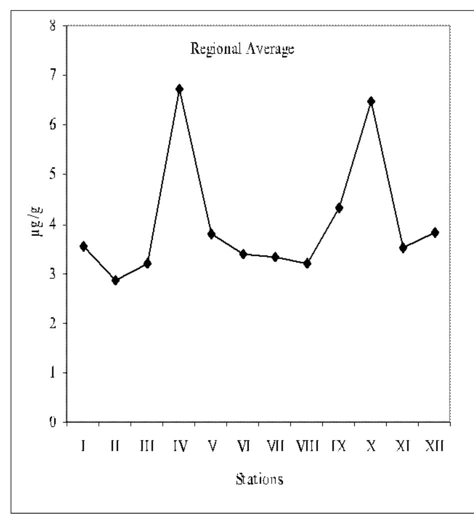


Fig. 3.8. **Regional variations of orthophosphate in the sediments of Bardawil Lagoon during 2004.**

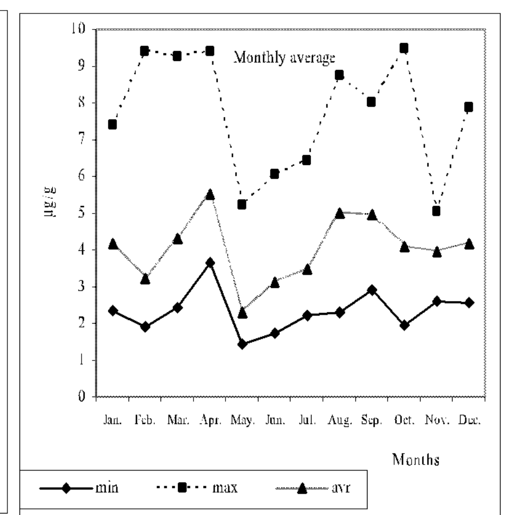


Fig. 3.9. **Maximum, minimum and monthly average variations of orthophosphate in the sediments of Bardawil Lagoon during 2004.**

The orthophosphate values showed irregular monthly variations (Fig. 3.9). In the same time, maximum regional values were recorded at the two artificail openings (Fig. 3.8). These data were concordant with the data obtained for water where the regional average values of water's orthophosphate showed that, Boughazes areas have the higher orthophosphate contents and decreased gradually southward. This observation indicated that orthophosphates are transported from see water into the lagoon and consequently precipitated due to higher salinity of lagoon water than the see water. Phosphorus forms chemically tight compounds with major cations; these tight forms especially noted with magnesium (in the form of $MgPO_4$; $MgHPO_4$ and MgH_2PO_4) and calcium (in the form of $CaPO_4$; $CaHPO_4$ and CaH_2PO_4 (Pulmmer *et al.* 1984).

3.4 HEAVY METALS

Metals have become a matter of concern and increasing significance. All metals can be toxic in certain forms or at some level. The term toxic is used in this section to describe metal species, which can readily bioaccumulate in the human body through the food chain and produce chronic or acute effects at relatively low concentrations. The potential ecotoxical effects of metals such as cadmium, lead, and mercury relate to their ability to accumulate in the vital organs of man and animals, as they accumulate in the body, they may produce progressively increasing toxic effects over the life span of the individual. Therefore, an important task of environmental protection is to control the anthropogenic input of toxic metals to the environment (Ravera 2001).

Metals tend to accumulate in lake sediments, and assessments of the degree of toxic metal accumulation generally involve sediment analyses. Due to the complex nature of lake ecosystems the use of total sediment metal concentrations have proven effective in predicting effects of metals on ecosystems. There is an extremely wide variation in lake sediment toxicity although total concentrations in sediments may be identical

Heavy metal deposits in lake sediments can become a long term hazard because they may in some instances be continuously released into the water. This effect can be enhanced if the organics, which may attach to the metals, form compounds more soluble in water, thereby increasing their bioavailability.

As a general rule, heavy metals are toxic, but are often complexes with insoluble compounds and be not toxic. However, acid waters may dissolve more metals than non-acid waters. Concentrations of several metals, including mercury and zinc, increase in acidic waters. Changes in the pollutant toxicity in response to other physiochemical factors are common and these interactions are called synergisms (Ravera 2001).

Iron

Iron values in the sediment of Bardawil Lagoon varied in similar trend as in water, with obvious increase during summer and spring more than during autumn and winter. This increase of iron concentration is attributed to the high level of dissolved oxygen contents which facilitate the oxidation of Fe^{+2} to Fe^{+3} (higher oxidation state) and lead to precipitation of $Fe(OH)_3$ to bottom sediment (Elewa *et al.* 2001). On the other hand, fermentation processes and decomposition of organic matter have a major role in increasing iron concentrations under elevated temperature and microbial activity (Hassouna 1989). The highest value of 8.64 mg/g was recorded during summer at station VIII, while the minimum value of 2.92 mg/g was recorded during autumn at Boughaze II, with annual mean value of 5.31 ± 0.85 mg/g (Table 3.4).

The recent data showed obvious decrease in iron value than that recorded by Lotfy (2003b) and Abdo (2005) who recorded maximum iron value of 15.6 and 17.06 mg/g during winter and summer 2000, respectively.

Manganese

Manganese exists in the soil principally as MnO_2 which is insoluble in water under reducing conditions, manganese found in the dioxide form is reduced from valence 4 to 2 and solution occurs always as with ferric oxide (Sawary & Mecarty 1967).

Manganese contents showed increase values during hot seasons than cold seasons, attributed to the decomposition of organic debris by microbial activity (Sung & Morgan 1981). The highest value of 235 µg/g was recorded during summer at station I (El-Telul area), while the minimum value of 115 µg/g was recorded during autumn at station VII with annual mean values of 171 ± 17.9 µg/g (Table 3.4).

Zinc

Zinc occurs in sediments as zinc carbonate, zinc oxide and zinc sulphide (Anon 1978). In addition, the organic matter enrichment in the sediment increases the deposition of zinc to sediment (Elewa *et al.* 1990).

Zinc values showed irregular distribution pattern along Bardawil Lagoon, but increased slightly towards western sector at stations XI and XII, mainly attributed to the precipitation of zinc from water to bottom sediment as zinc carbonate under the influence of high salinity (Goher 2002). The highest value of 51 µg/g was recorded during spring at Boughaze II, while the minimum value of 23 µg/g was recorded during autumn at station IX, with an annual mean of 34.2 ± 1.2 µg/g (Table 3.4).

Table 3.3. **Range, annual mean ± standard deviation of basic nutrient salts (nitrite, nitrate, ammonia and orthophosphate) in the sediments of Bardawil Lagoon during 2004 (Abdel-Karim *et al.* 2006).**

Parameter	NO_2 (µg/g)		NO_3 (µg/g)		NH_4 (µg/g)		PO_4 (µg/g)	
Station	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**
I	0.19 - 1.26	0.58 ± 0.37	0.99 - 5.42	2.9 ± 1.2	147.3 - 327.9	239.4 ± 63.1	2.30 - 4.95	3.54 ± 1.0
II	0.11 - 1.15	0.46 ± 0.36	0.90 - 3.70	2.5 ± 1.0	64.1 - 160.1	123.5 ± 28.8	1.90 - 4.60	2.86 ± 0.9
III	0.20 - 1.13	0.60 ± 0.30	0.95 - 3.66	2.4 ± 0.8	127.5 - 318.6	188.7 ± 69.8	1.65 - 8.0	3.20 ± 1.6
IV	0.17 - 0.96	0.41 ± 0.26	1.59 - 5.38	3.4 ± 1.3	7.4 - 100.5	46.7 ± 28.9	3.05 - 9.50	6.73 ± 2.3
V	0.09 - 1.20	0.53 ± 0.36	1.25 - 4.30	2.8 ± 1.0	43.8 - 246.9	140.6 ± 53.9	1.65 - 6.65	3.78 ± 1.5
VI	0.09 - 1.18	0.65 ± 0.40	1.63 - 4.64	3.4 ± 1.0	44.1 - 206.4	98.3 ± 55.3	1.60 - 5.30	3.40 ± 1.3
VII	0.22 - 1.54	0.71 ± 0.47	1.98 - 4.30	3.1 ± 0.7	8.6 - 168.2	92.6 ± 56.0	1.85 - 5.05	3.32 ± 0.9
VIII	0.06 - 1.09	0.46 ± 0.36	1.33 - 4.69	2.6 ± 1.2	8.3 - 201.5	87.3 ± 67.4	1.45 - 6.95	3.22 ± 1.5
IX	0.19 - 0.98	0.59 ± 0.29	0.82 - 4.43	3.3 ± 1.0	39.0 - 155.3	83.1 ± 34.8	2.20 - 7.40	4.32 ± 1.6
X	0.11 - 1.17	0.42 ± 0.36	1.51 - 5.59	3.7 ± 1.2	21.9 - 59.4	39.6 ± 13.4	2.75 - 9.40	6.30 ± 2.8
XI	0.11 - 0.80	0.48 ± 0.24	1.81 - 4.52	2.9 ± 0.7	58.8 - 208.8	118.6 ± 44.9	2.40 - 6.65	3.53 ± 1.2
XII	0.09 - 1.09	0.59 ± 0.37	1.81 - 3.96	3.0 ± 0.6	31.8 - 113.3	72.7 ± 26.9	1.90 - 6.45	3.83 ± 1.2
Mean	0.06 – 1.54	0.54 ± 0.28	5.38	3.0 ± 0.68	7.4 – 327.9	108.0 ± 33.6	1.45 – 9.5	4.01 ± 0.9

Copper

Copper may be incorporated in clay minerals after decomposition of organic matter by adsorption on the surface of clay minerals. The biogenic form of copper occurs when dead microorganisms are decayed in the bottom and release copper to the contact sediment (Salomons & Forstner 1984).

Contrary to the distribution of copper in lagoon's water, its values in sediments showed increase during spring and summer more than during autumn and winter, mainly attributed to the precipitation of copper from water to the sediment as CuS under elevation of temperature (Hutchinson 1957). The highest value of 9.3 µg/g was recorded during spring at Boughaze II, while the minimum value of 4.3 µg/g was recorded during autumn at station IX, with an annual mean of 6.3 ± 0.2 µg/l (Table 3.4).

Lead

Lead arises from several human-made sources including automobile exhaust, smelting operations, paints, and coal combustion. Atmospheric deposition, point sources, bedrock geology, and storm water runoff are likely sources of lead to lakes. In general, Tetraethyl lead (in gasoline) was a major source of lead in the atmosphere, soil and water (Davis & Galloway 1981).

Lead distribution pattern in sediments acts in harmony with their values in water. However, the obtained results showed slight increase during spring and summer more than that recorded during autumn and winter. The highest value of 23.9 µg/g was recorded during summer at station I (El-Telul area) while the minimum value of 11.7 µg/g was recorded during autumn at station VII, with an annual mean of 17.3 ± 1.8 µg/g (Table 3.4).

In general, heavy metals concentrations in Bardawil sediments vary within a narrow range among different stations and seasons, their higher values were recorded at station I (El-Telul area) due to the tailings of fishermen and at Boughaze II area due to intrusion of sea water which carried suspended matter bearing most metals from the sea.

Comparison with the Other Water Bodies

Heavy metals concentrations in the sediments of Lake Bardawil, as mentioned in 2004, are much lower than those of Burullus and Qarun Lakes (El-Nemer *et al.* 2003, Goher 2002, respectively). On the other hand, the annual average is less than the permissible standard levels for all the studied metals (Table 3.5).

Table 3.4. **Range, annual mean ± standard deviation of heavy metals (iron, manganese, zinc, copper and lead) in the sediments of Bardawil Lagoon during 2004 (Abdel-Karim *et al.* 2006).**

Stations	Fe (mg/g)		Mn (µg/g)		Zn (µg/g)		Cu (µg/g)		Pb (µg/g)	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
I	5.46 - 7.85	6.32 ± 1.08	165 - 235	202.3 ± 29.9	30 - 45	37.5 ± 6.5	5.5 - 8.3	6.93 ± 1.2	16.8 - 23.9	20.5 ± 3.0
II	4.69 - 6.34	5.30 ± 0.74	142 - 215	170.5 ± 31.3	27 - 35	30.0 ± 3.6	5.0 - 6.4	5.56 ± 0.6	14.4 - 21.8	17.3 ± 3.2
III	3.97 - 6.6	5.12 ± 1.10	132 - 178	152.3 ± 22.4	26 - 31	28.3 ± 2.6	4.7 - 5.7	5.20 ± 0.5	13.4 - 18.1	15.5 ± 2.3
IV	5.31 - 6.64	5.97 ± 0.71	150 - 184	168.3 ± 14.4	34 - 51	41.5 ± 7.9	6.5 - 9.3	7.68 ± 1.4	15.2 - 18.7	17.1 ± 1.5
V	2.92 - 4.17	3.71 ± 0.55	155 - 202	180.0 ± 23.5	28 - 38	31.5 ± 4.5	5.2 - 7.0	5.84 ± 0.8	15.8 - 20.5	18.3 ± 2.4
VI	3.43 - 5.65	4.51 ± 0.92	135 - 185	157.8 ± 22.3	35 - 46	39.0 ± 5.0	6.5 - 8.4	7.13 ± 0.9	13.7 - 18.8	16.0 ± 2.3
VII	3.50 - 5.66	4.71 ± 0.98	115 - 145	132.1 ± 12.5	30 - 48	37.3 ± 8.1	5.5 - 8.8	6.83 ± 1.5	11.7 - 14.7	13.4 ± 1.3
VIII	5.30 - 8.46	6.49 ± 1.40	175 - 218	194.0 ± 20.9	26 - 37	30.8 ± 5.2	4.8 - 6.9	5.70 ± 1.0	17.8 - 22.1	19.7 ± 2.1
IX	4.47 - 6.58	5.46 ± 1.13	139 - 163	151.0 ± 11.0	23 - 26	24.5 ± 1.3	4.3 - 5.8	4.78 ± 0.7	14.1 - 16.5	15.3 ± 1.1
X	5.59 - 7.15	6.33 ± 0.70	155 - 181	168.3 ± 11.9	32 - 39	34.8 ± 3.1	5.8 - 7.2	6.40 ± 0.6	15.7 - 18.4	17.1 ± 1.2
XI	4.12 - 6.73	5.22 ± 1.27	160 - 201	177.8 ± 18.1	33 - 46	39.0 ± 5.7	6.1 - 8.5	7.18 ± 1.1	16.2 - 20.4	18.1 ± 1.8
XII	3.72 - 6.10	4.83 ± 1.01	164 - 215	195.0 ± 23.7	30 - 41	36.3 ± 5.6	5.5 - 7.5	6.55 ± 0.9	16.7 - 21.8	19.8 ± 2.4
Mean	2.92 – 8.46	5.33 ± 0.89	115 - 218	170.8 ± 17.9	26 - 51	34.2 ± 1.2	4.3 – 9.3	6.31 ± 0.2	11.7 – 22.1	17.3 ± 1.8

Table 3.5. **Comparison between mean values of heavy metals in the sediments of Bardawil Lagoon and other lakes.**

Location	Fe (mg/g)	Mn (µg/g)	Zn (µg/g)	Cu (µg/g)	Pb (µg/g)
Bardawil Lagoon, Egypt (Abdel-Karim *et al.* 2006)	5.33	170	34.2	6.3	17.3
Bardawil Lagoon Egypt (Abdo 2005)	10.1	240	33.5	34.5	15.6
Burullus Lake Egypt (El-Nemr 2003)	25.2	*	78.4	113.1	60.2
Edku Lake Egypt	8.5	1499	*	298	40
Qarun Lake Egypt (Goher, 2002)	27.4	535	195	55.9	33.95
Tuskegee Lake U.S.A (Ikem *et al.* 2003)	3.16	53.4	8.72	6.84	14.8
St. Louis Bay MS U.S.A. (Lytle & Lytle 1980)	7.8	75	47	6.38	12.24
Latvia Lake Latvia (Klavinš *et al.* 1998)	6.5	81.17	78.43	16.34	83.21
Siberian Lake Russia (Kirby *et al.* 2001)	21	671	115.8	20.5	16.6
Low Permissible level (Allen-Gil *et al.* 1997)	**NA**	**600**	**225**	**125**	**45**

3.5 SUMMARY

Sediments in Bardawil Lagoon consist mainly of sand (72 %), mud (19 %) and very little amount of gravel size (9 %). In general, sediments of Boughaze area maintained the highest sand fractions (98.1 %), followed by low gravel percentage (1.9 %) and complete absence of mud fractions. Meanwhile, the lowest sandy fractions (61.2 %) were found in the eastern part of the lagoon with the highest mud fractions (27.5 %), which could be attributed to the movement of mud, which resulted from dredging processes at Boughaze.

Sediments of Bardawil lagoon mostly lie in the alkaline side except in hot months (June – August) when it lies in acidic side. The pH values are in the ranges of 6.47 - 7.92 with an annual average of 7.33. The organic matter content varied in the range of 0.9 - 13.3 % with annual average value of 4.5 ± 0.06. Carbonate contents varied in the range of 4.0 - 37.9 % with an annual average of 22.8 ± 0.6 %.

Exchangeable nutrient salts had the decreasing order of NH4+ > PO4 > NO3 > NO2 with annual mean values of 108, 4, 3 and 0.54 µg/g, respectively. Their values were varied in the ranges of; 7.4 – 327.9, 1.45 – 9.5, 0.82 – 5.59 and 0.06 – 1.54 µg/g, respectively.

Heavy metals were found in the ranges of 2.92 – 7.85 mg/g, 115 - 235, 26- 51, 4.3 – 9.3 and 11.7 – 22.1 µg/g for Fe, Zn, Mn, Pb and Cu respectively. Their annual mean values had the decreasing order of Fe > Mn > Zn > Pb > Cu,

with annual mean values of 5.33 mg/g, 170.8, 34.2, 17.3, 6.3 µg/g, respectively. These values are below the standard permissible values cited by the World Health Organization (WHO) and European Economic Community (EEC).

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Chapter 4
Flora and Vegetation

4.1 FLORISTIC FEATURES

A total of 136 species belonging to 109 genera and 42 families were recorded in Lake Bardawil by El-Bana (2003) and Khedr and El-Gazzar (2000) (Table 4.1). This number is about 36% of the recorded species in the Mediterranean coastal plain of Sinai (Gibali 1988) and about 34% % of the recorded species in the northern lakes of Egypt (Shaltout and Galal 2006). Gramineae had the highest contribution (12.5%) followed by Chenopodiaceae (11.0%) (Fig. 4.1). Sixty-nine species were recorded only in Lake Bardawil (about half of the recorded species in this lake) and not in the other northern lakes (Mariut, Edku, Burullus and Manzala), of these; 25 species are annuals such as *Aegilops kotschyi, Asphodelus viscidulus, Crucianella membranacea, Euphorbia granulata, Plantago cylindrica* and *Stipa capensis*; and 44 species are perennials such as *Allium papillare, Atractylis carduus, Echiochilon fruticosum, Eremobium aegyptiacum and Ruppia cirrhosa*. Most of these species are halophytes, which may be expected to express a better adaptation to high salinity that characterizes this lake (Krumglaz *et al.* 1980).

4.1.1 Habit of Species

Seventy-nine species (58.1% of the total recorded species) are perennials and 57 species (41.9% of the total recorded species) are annuals (Table 4.1). On the other hand, 104 species (76.5% of the total recorded species) are natural plants, 27 (19.9%) are terrestrial weeds, 4 (2.9%) are aquatic weeds and only one species (0.7%) is an escape from cultivation (Fig. 4.2). The relatively low number of aquatic species may be attributed to salinity as that Lake Bardawil has no connections with a source of fresh water from the Nile. Lake Bardawil is characterized by limited number of hydrophytes (three sea grasses: *Ruppia cirrhosa, Cymodocea nodosa* and *Halodule uninervis*), the outskirts show the dominance of psamophytes and xerophytes. Most of these species are present in communities that prevail in the desert dunes and wadis south and south-east of Lake Bardawil (Zahran & Willis 1992). This indicates that the flora of Lake

Bardawil seem more related to the southern desert flora than to the flora of the Mediterranean, and this may be attributed to the fact that Lake Bardawil sediments were supplied by desert inland wadis like wadi El-Arish (Shukri & Philip 1960). The previous reasons may explain the higher number of natural plants of Lake Bardawil compared with the other northern lakes.

Table 4.1. **Floristic categories and life forms of the species recorded in Lake Bardawil. The naturalness status are: AW= aquatic weed, TW= terrestrial weed, EP= escape from cultivation, NP= natural plants. The life forms are: Ph= phanerophyte, Ch= chamaephyte, GH= geophyte-helophyte, Hc= hemicryptophyte, Hh= hydrophyte, Pa= parasite, Th= therophyte. The floristic category are: ME= Mediterranean, COSM= Cosmopolitan, SA-SR= Saharo-Arabian,Trop: Tropical, S-Z= Sudano-Zambezian, MA= Malysian, ER-SR= Euro-Siberian, IR-TR= Irano-Turanian, GC= Guineo-Congolese, IN= Indian, PAL= Palaeotropical, PAN= Pantropical, Temp= Temperate and NEO= Neotropical.**

Species	Status	Habit	Life form	Floristic category	Vernacular name
Ephedraceae					
Ephedra alata Decne.	NP	Perennial	Ch	SA-AR	علدة الدباغ
Polygonaceae					
Calligonum polygonoides L.	NP	Perennial	Ph	IR-TR+SA-AR	ارطى
Rumex pictus Forssk.	NP	Annual	Th	ME+SA-AR	حمصيص
Aizoaceae					
Mesembryanthemum crystallinum L.	NP	Annual	Th	ME+ER-SR	غسول
Mesembryanthemum forsskaolii Hochst. ex Boiss.	NP	Annual	Th	S-Z	صوابع الهانم
Mesembryanthemum nodiflorum L.	NP	Annual	Th	ME+ER-SR+SA-AR	سمح
Caryophyllaceae					
Gymncarpos decandrus Forssk.	NP	Perennial	Gh	SA-AR	جرد
Herniaria hemistemon J. Gay	NP	Annual	Th	SA-AR	أم لبيد
Herniaria hirsuta L.	NP	Annual	Th	ME+ER-SR+IR-TR	أم لبيد
Paronychia arabica (L.) DC.	NP	Annual	Th	ME+SA-AR+S-Z	نخال
Paronychia argentea Lam.	NP	Perennial	Hc	ME	بساط الأرض
Polycarpaea repens (Forssk.) Asch. & Schweinf.	NP	Perennial	Ch	S-Z	دقيقه
Polycarpon succulentum (Delile) J. Gay	NP	Annual	Th	SA-AR	ريحاى
Silene villosa Forssk.	NP	Annual	Th	SA-AR	عطان
Spergularia marina (L.) Bessler	TW	Perennial	H	ME+ER-SR+IR-TR	أبو غلام
Chenopodiaceae					
Anabasis articulata (Forssk.) Moq.	NP	Perennial	Ch	SA-AR	عجرام
Arthrocnemum macrostachyum (Moric.) K. Koch	NP	Perennial	Ch	ME+SA-AR	شنان
Bassia muricata (L.) Asch.	NP	Annual	Th	IR-TR+SA-AR	هيثام
Cornulaca monacantha Delile	NP	Perennial	Ch	SA-AR+S-Z+IN	حار
Halocnemum strobilaceum (Pall.) M. Bieb.	NP	Perennial	Ch	ME+SA-AR+IR-TR	حطب حدادى
Haloxylon scoparium Pomel	NP	Perennial	Ch	IR-TR+SA-AR	طفوه
Noaea mucronata (Forssk.) Asch. & Schweinf.	NP	Perennial	Ch	IR-TR	أثير
Salicornia europaea L.	NP	Annual	Th	ME+ER-SR	أبو ساق
Salsola kali L.	NP	Annual	Th	COSM	إشنان
Salsola tetragona Delile	NP	Perennial	Ch	SA-AR	زمران
Sarcocornia fruticosa (L.) A. J. Scott.	NP	Perennial	Ch	SA-AR	أبو ساق
Suaeda aegyptiaca (Hasselq.) Zohary	NP	Perennial	Ch	SA-AR	حطب سويدى
Suaeda maritima (L.) Dumort.	NP	Annual	Th	COSM	خريزة

Species	Status	Habit	Life form	Floristic category	Vernacular name
Suaeda vera Forssk. Ex. J. F. Gmel.	NP	Perennial	Ch	ME+ER-SR+SA-AR	سبطة
Traganum nudatum Delile	NP	Perennial	Ch	SA-AR	فرس
Ranunculaceae					
Adonis dentata Delile	TW	Annual	Th	ME+SA-AR+IR-TR	ناب الجمل
Cleomaceae					
Cleome amblyocarpa Barratte & Murb.	NP	Annual	Th	SA-AR+S-Z	هنديب
Cruciferae					
Brassica tournefortii Gouan	TW	Annual	Th	ME+SA-AR+IR-TR	شرطام
Cakile maritima Scop.	NP	Annual	Th	ME+IR-TR	رشاد البحر
Eremobium aegyptiacum (Spreng.) Asch. & Schweinf. ex Boiss.	NP	Perennial	He	SA-AR	دخيان
Erucaria hispanica (L.) Druce	NP	Annual	Th	ME	روق
Lobularia arabica (Boiss.) Muschl.	NP	Annual	Th	SA-AR	دحيان
Neuradaceae					
Neurada procumbens L.	NP	Annual	Th	SA-AR	ضريس
Leguminosae					
Argyrolobium uniflorum (Decne.) Jaub. & Spach	NP	Perennial	Ch	SA-AR	كود
Astragalus annularis Forssk.	NP	Annual	Th	SA-AR	كداد
Astragalus boeticus L.	NP	Annual	Th	ME	محلاق
Astragalus camelorum Barbey	NP	Perennial	Ch	Endemic	كداد
Astragalus fruticosus Forssk.	NP	Perennial	He	SA-AR	زب الكلب
Astragalus kahiricus DC.	NP	Perennial	He	SA-AR	زب القط
Hippocrepis areolata Desv.	TW	Annual	Th	ME+SA-AR	ضريس
Lotus halophilus Boiss. & Spruner	NP	Annual	Th	ME+SA-AR	حربيث
Ononis serrata Forssk.	NP	Annual	Th	ME+SA-AR	حطيبه
Retama raetum (Forssk.) Webb & Berthel	NP	Perennial	Ph	SA-AR	الرتم
Trigonella stellata Forssk.	TW	Annual	Th	IR-TR+SA-AR	شطن الخادم
Geraniaceae					
Erodium laciniatum (Cav.) Willd.	NP	Annual	Th	ME	أبو مصفاح
Zygophyllaceae					
Fagonia arabica L.	NP	Perennial	Ch	ER-SR	شويكة
Peganum harmala L.	NP	Perennial	He	IR-TR+SA-AR	حرمل
Zygophyllum aegyptium Hosny	NP	Perennial	Ch	Endemic	رطريط
Zygophyllum album L.f.	NP	Perennial	Ch	ME+SA-AR	رطريط
Zygophyllum coccineum L.	NP	Perennial	Ch	SA-AR	رطريط
Nitrariaceae					
Nitraria retusa (Forssk.) Asch.	NP	Perennial	Ph	SA-AR	غرقد
Euphorbiaceae					
Euphorbia granulata Forssk.	TW	Annual	Th	SA-AR	ملبين
Rutaceae					
Haplophyllum tuberculatum (Forssk.) Juss.	NP	Perennial	Ch	SA-AR	شجرة الكلب

Species	Status	Habit	Life form	Floristic category	Vernacular name
Malvaceae					
Malva parviflora L.	TW	Annual	Th	ME+IR-TR	خبيزة
Thymellaceae					
Thymelaea hirsuta (L.) Endl.	NP	Perennial	Ch	ME+SA-AR	متنان
Cistaceae					
Helianthimum stipulatum (Forssk.) C. Chr.	NP	Perennial	Ch	SA-AR	رعل
Tamaricaceae					
Tamarix amplexicaulis Ehrenb.	NP	Perennial	Ph	SA-AR+S-Z	طرفه
Tamarix nilotica (Ehrenb.) Bunge	NP	Perennial	Ph	SA-AR+S-Z	مور
Frankeniaceae					
Frankenia hirsuta L.	NP	Perennial	Hc	ME+ER-SR	غبيرة
Frankenia pulverulenta L.	NP	Annual	Th	ME+ER-SR+IR-TR	حميشة
Umbelliferae					
Bupleurum semicompositum L.	NP	Annual	Th	ME+SA-AR+IR-TR	اذان الفار
Daucus littoralis var. littoralis Sm.	TW	Annual	Th	ME	جزيرة
Deverra tortuosa (Desf.) DC.	NP	Perennial	Ch	SA-AR	قزوح
Plumbaginaceae					
Limoniastrum monopetalum (L.) Boiss.	NP	Perennial	Ch	ME	زيتة
Limonium pruinosum (L.) Chaz.	NP	Perennial	Ch	ME	مليح
Rubiaceae					
Crucianella membranacea Boiss.	NP	Annual	Th	SA-AR	عدرس
Convolvulaceae					
Convolvulus lanatus Vahl	NP	Perennial	Ch	SA-AR	بياض
Cressa critica L.	TW	Perennial	Hc	ME+IR-TR+Trop	أبو حصابة
Boraginaceae					
Anchusa humilis (Desf.) I. M. Johnst.	NP	Annual	Th	SA-AR	كحله
Echiochilon fruticosum Desf.	NP	Perennial	Ch	SA-AR	جرشه
Echium angustifolium Mill.	NP	Perennial	Ch	ME	حنا الغول
Heliotropium digynum (Forssk.) Asch.ex. C. Chr.	NP	Perennial	Ch	SA-AR	حلانيه
Moltkiopsis ciliata (Forssk.) I. M. Johnst.	NP	Perennial	Ch	SA-AR	حلمة
Labiatae					
Salvia lanigera Poir.	NP	Perennial	Ch	ME+SA-AR	زيته
Solanaceae					
Lycium shawii Roem. & Schult.	NP	Perennial	Ph	SA-AR+S-Z	عوسج
Solanum elaeagnifolium Cav.	NP	Perennial	Ch	ME	
Scrophulariaceae					
Linaria haelava (Forssk.) Delile	NP	Annual	Th	SA-AR	ذنب الفار
Orobanchaceae					
Cistanche phelypaea (L.) Cout.	NP	Perennial	Pa	ME+SA-AR	دنون
Cistanche salsa (C. A. Mey.) Beck	NP	Perennial	Pa	IR-TR	دنون
Orobanche cernnua Loefl.	TW	Perennial	Pa	ME+SA-AR+IR-TR	هالوك

Species	Status	Habit	Life form	Floristic category	Vernacular name
Plantaginaceae					
Plantago albicans L.	NP	Perennial	Hc	ME+SA-AR	لقمة النعجة
Plantago cylindrica Forssk.	NP	Annual	Th	SA-AR	برخمى
Plantago ovata Forssk.	NP	Annual	Th	IR-TR+SA-AR	دقيس
Compositae					
Artemisia monosperma Delile	TW	Perennial	Ch	SA-AR	بعيثران
Atractylis carduus (Forssk.) C. Chr.	NP	Perennial	Ch	SA-AR	عكش
Centauria calcitrapa L.	TW	Perennial	Ch	ME+ER-SR	شوك
Cotula cinerea Delile	TW	Annual	Th	SA-AR	افرش
Echinops spinosus L.	NP	Perennial	Hc	ME+SA-AR	شوك الجبل
Filago desertorum Pomel	NP	Annual	Th	IR-TR+SA-AR	---
Iflago spicata (Forssk.) Sch.Bip.	NP	Annual	Th	ME+SA-AR	شجرة المعيز
Launaea capitata (Spreng) Dandy	NP	Annual	Th	SA-AR+S-Z	الأنيات
Launaea fragilis (Asso) Pau	NP	Perennial	Hc	SA-AR	حوا
Launaea nudicaulis (L.) Hook. F.	NP	Perennial	Hc	SA-AR+IR-TR+S-Z	حوا
Reichardia tingitana (L.) Roth	NP	Annual	Th	IR-TR+SA-AR	عضيد
Senecio glaucus spp. glaucus L.	TW	Annual	Th	IR-TR+SA-AR	قريص
Soncuhs oleraceous L.	TW	Annual	Th	COSM	جعضيض
Ruppiaceae					
Ruppia cirrhosa (Petagna) Grande	AW	Perennial	Hh	Pluri.	ريم
Cymodoceaceae					
Cymodocea nodosa (Ucria) Asch.	AW	Annual	Th	ME+ER-SR	قشر
Halodule uninervis (Forssk.) Asch.	AW	Annual	Th	Trop	---
Liliaceae					
Asparagus stipularis Forssk.	NP	Perennial	Gh	ME+SA-AR	عقول برى
Asphodelus viscidulus Boiss.	TW	Annual	Th	SA-AR	بصل الشيطان
Bellevalia salah-eidii Taekh. & Boulos	NP	Perennial	Gh	Endemic	بصيل
Dipcadi erythraeum Webb. & Berthel	NP	Perennial	Gh	SA-AR	بريد الكلب
Muscari bicolor Boiss.	NP	Perennial	Gh	ME	---
Alliaceae					
Allium curtum Boiss. & Gaill.	NP	Perennial	Gh	ME+IR-TR	زعيطمان
Allium papillare Boiss.	NP	Perennial	Gh	Endemic	زعيطمان
Amaryllidaceae					
Pancratium maritimum L.	NP	Perennial	Gh	ME	زمبق
Pancratium sickenbergeri Asch. & Schweinf.	NP	Perennial	Gh	SA-AR	عيصلان
Iridaceae					
Iris mariae Barbey	NP	Perennial	Gh	Endemic	إيرس
Juncaceae					
Juncus rigidus Desf.	TW	Perennial	Gh	ME+SA-AR+IR-TR	سمار حصر
Gramineae					
Aegilops kotschyi Boiss.	NP	Annual	Th	IR-TR+SA-AR	شعير الفار

Species	Status	Habit	Life form	Floristic category	Vernacular name
Avena barbata Pott ex Link	TW	Annual	Th	ME+ER-SR+IR-TR	بهمى
Brachypodium distachyum (L.) P. Beauv.	TW	Annual	Th	ME+IR-TR	ياداب
Bromus lanceolata Roth	TW	Annual	Th	ME+IR-TR	خفور
Bromus rubens L.	TW	Annual	Th	ME+SA-AR+IR-TR	ديل التعلب
Centropodia forsskaolii (Vahl) Cope	NP	Perennial	Hc	IR-TR+SA-AR	عكريش
Cutandia dichotoma (Forssk.) Trab.	TW	Annual	Th	IR-TR+SA-AR	خفور
Cutandia memphitica (Spreng.) K. Richt.	TW	Annual	Th	ME+SA-AR+IR-TR	صامه
Cynodon dactylon (L.) Pers.	TW	Perennial	Gh	COSM	نجيل
Panicum turgidum Forssk.	NP	Perennial	Gh	SA-AR+S-Z	أثمام
Phragmites australis (Cav.) Trin.ex Steud	AW	Perennial	Gh	COSM	حجنة
Poa annua L.	TW	Annual	Th	ME+ER-SR+IR-TR	سبل ابو الحسين
Schismus arabicus Nees	NP	Annual	Th	IR-TR+SA-AR	بهمى
Stipa capensis Thunb.	NP	Annual	Th	IR-TR+SA-AR	أبو فاخور
Stipagrostis ciliata (Desf.) de Winter	NP	Perennial	Hc	SA-AR	الصحن
Stipagrostis plumosa (L.) Munro ex T. Anderson	NP	Perennial	Hc	IR-TR+SA-AR	نوى بيضه
Stipagrostis scoparia (Trin. & Rupr.) de Winter	NP	Perennial	Hc	SA-AR	نصى
Palmae					
Phoenix dactylifera L.	EP	Perennial	Ph	SA-AR+S-Z	نخيل البلح
Araceae					
Biarum olivieri Blume	NP	Perennial	Gh	SA-AR	---
Cyperaceae					
Cyperus conglomeratus Rottb.	TW	Perennial	Hc	ME	عشوب
Cyperus laevigatus L.	TW	Perennial	Gh	ME+SA-AR+IR-TR	بربيط

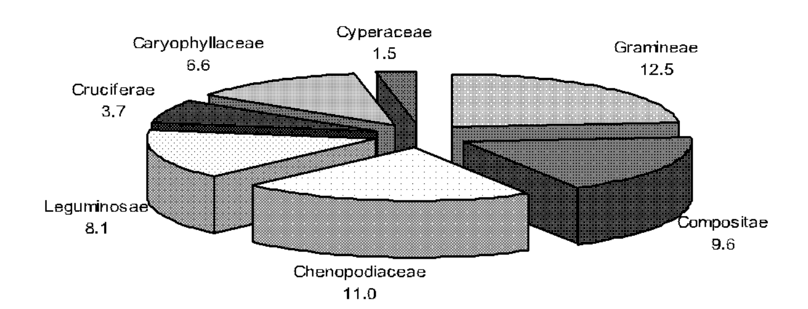


Fig. 4.1. **The characteristic families of vascular plants in Lake Bardawil.**

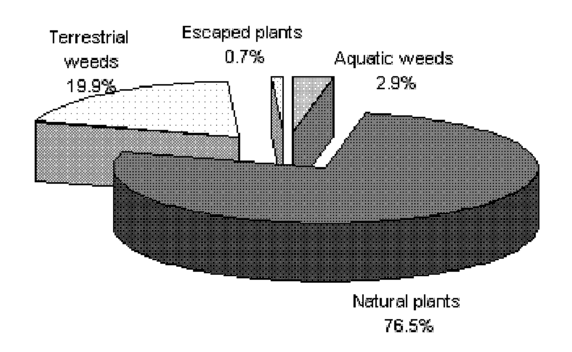


Fig. 4.2. **Status of species in Lake Bardawil.**

4.1.2 Life Forms

The life form of the plant is thought to be usually a hereditary adjustment to environment and may be considered as registration apparatus of the habitat (Bakker 1966). The life form spectra provide information, which may help in assessing the response of vegetation to variations in environmental factors (Ayyad & El-Ghareeb 1982). Raunkiaer (1937) designated the Mediterranean climate type as a "therophyte climate" because of the high percentage (more than 50% of the total species) of this life form in several Mediterranean floras (Raven 1971). This is later confirmed by Hassib (1951) in Egypt, Zohary (1973) in Palestine and Quezel (1978) in North Africa. Therophytes are the most represented in Lake Bardawil, followed by chamaephytes, geophytes–helophytes hemicryptophytes, phanerophytes, parasites and hydrophytes (Fig. 4.3). The high percentage of therophytes may be related to the arid climate and seasonal rainfall. This trend is similar to that of the whole Egyptian flora (Hassib 1951). Heneidy and Bidak (2001) point out that the dominance of therophytes over the other life forms seems to be a response to the hot-dry climate, long dry season, topographic variation and biotic influence. El-Ghareeb and Rezk (1989) provided evidence that therophytes acquire dominance in less saline and more sandy habitats, while cryptophytes and chamaephytes prevail in more saline habitats in the coastal area of Egypt. El-Demerdash (1984), Mashaly (1987), Shaltout & Sharaf El-Din (1988) and Shaltout *et al.* (1994) reported that the predominance of the cryptophytes in the salt marshes is probably attributed to their growth habits.

The high number of chamaephytes in Lake Bardawil may be attributed to the ability of species belonging to this life form to resist drought, salinity, sand accumulation and grazing (Danin 1996, El-Bana *et al.* 2002). Chamaephytes and geophytes are able to withstand water logging, high salinity levels and a wide range of temperature variability (Zahran 1982).

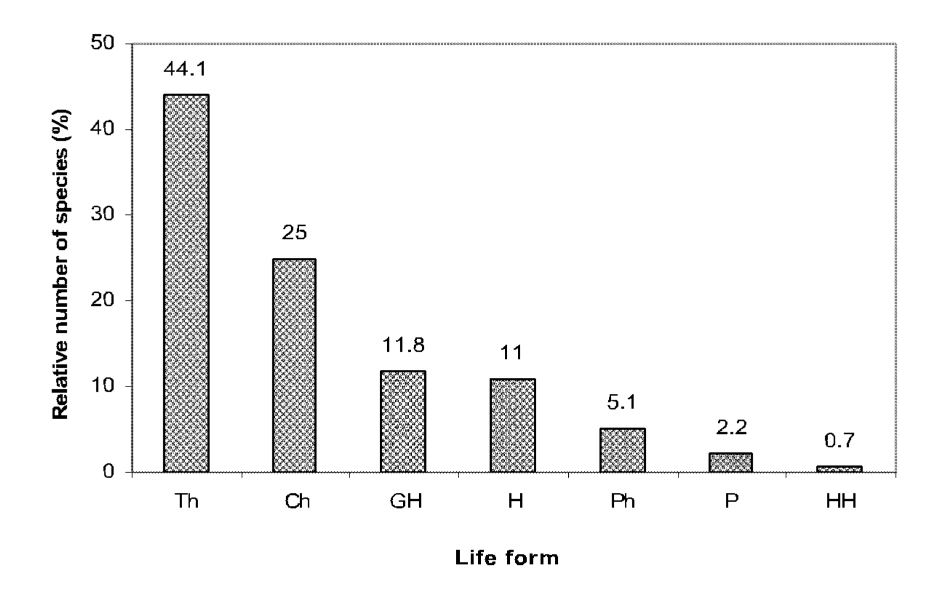


Fig.4.3. **Life form spectrum of the recorded species in Lake Bardawil. Ph: phanerophytes, Ch: chamaephytes, GH: geophytes-helophytes, Hc: hemicryptophytes, HH: hydrophytes, P: parasites and Th: therophytes**

4.1.3 Phytogeography and Abundance

Five species are cosmopolitan: *Cynodon dactylon, Phragmites australis, Salsola kali, Soncuhs oleraceous* and *Suaeda maritima* (Fig. 4.4). Sixty species (44.1% of the total recorded species) are monoregionals, 42 species of which are Saharo-Arabian (e.g. *Moltkiopsis ciliata, Polycarpon succulentum, Salsola tetragona, Suaeda aegyptiaca* and *Zygophyllum coccineum*), twelve species are Mediterranean taxa (e.g. *Cyperus conglomerates, Erucaria hispanica, Muscari bicolor, Paronychia argentea* and *Solanum elaeagnifolium*). 45 species (33.1% of the total recorded species) are bi-regionals. 43 species of which are Saharo-Arabian taxa penetrating other territories (e.g. *Lycium shawii, Calligonum polygonoides, Reichardia tingitana, Echinops spinosus* and *Lotus halophilus*), 23 species are Mediterranean taxa penetrating other territories (e.g. *Arthrocnemum macrostachyum, Cakile maritima, Cleome amblyocarpa, Frankenia hirsuta* and *Brachypodium distachyum*).

Twenty one species (15.4% of the total recorded species) are pluri-regionals: 14 species of which are Saharo-Arabian taxa penetrating other territories (e.g. *Mesembryanthemum nodiflorum, Cutandia memphitica, Halocnemum strobilaceum, Paronychia arabica* and *Launaea nudicaulis*) and 18 species are Mediterranean taxa penetrating other territories (e.g. *Avena barbata, Spergularia marina, Cressa critica, Brassica tournefortii* and *Juncus rigidus*). The percentage of endemic species is highest in insular floras, peninsulas and mountain chains (Bramwell as quoted by Ahmed 2003 and Strid 1986). Compared with the other northern lakes, the vegetation of Lake Bardawil

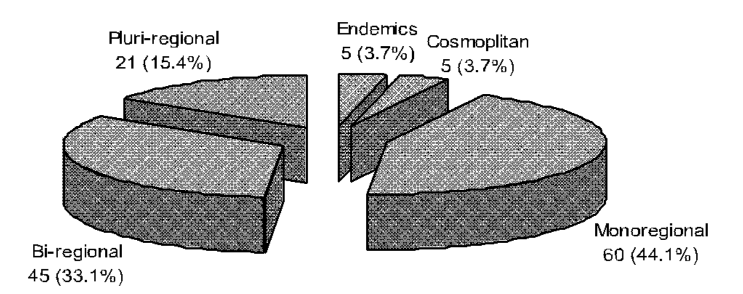


Fig. 4.4. **Geographical distribution (i.e. floristic regions) of the recorded species in Lake Bardawil.**

has a relatively high number of endemic species (5 species). Saharo-Arabian element forms the major floristic structure of Lake Bardawil. This confirms the bimodal nature of the Mediterranean coast of Sinai (Gibali 1988). Gibali (1988) suggested that the inland desert flora extend into the western Mediterranean coast of Sinai. On the other hand, the flora of the other lakes is mainly influenced by the pluri-regional chorotypes especially of Mediterranean combination. Zohary (1973) referred the dominance of inter-regional species (bi-, tri- and pluri-regionals) over mono regional ones to the presence of interzonal habitats, such as anthropogenic, hydro-, halo- and psammophilous sites. Mediterranean elements in the flora of Lake Bardawil contributed the lowest number of species (13.2% of the total species) compared with the other northern lakes. This was also confirmed by El-Demerdash *et al.* (1990) for the eastern Mediterranean Deltaic region.

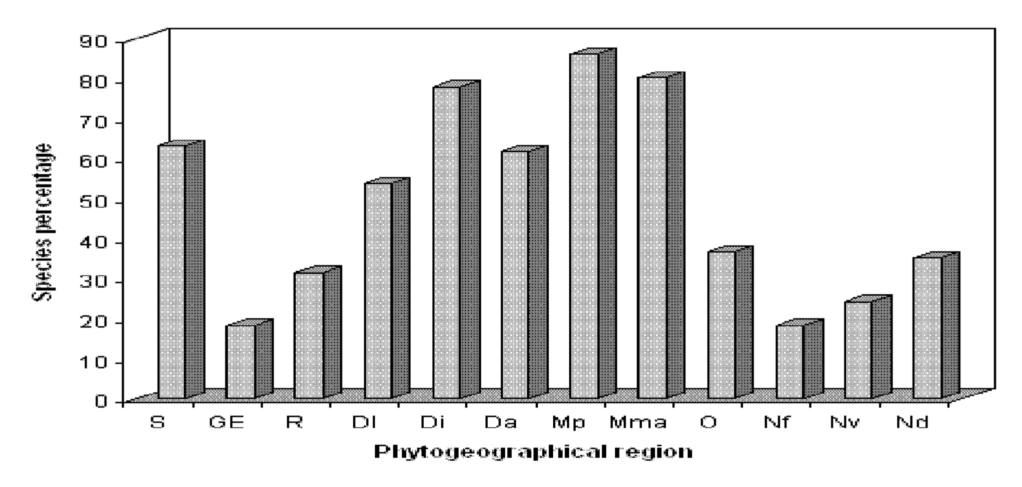


Fig. 4.5. **Percentage of the Bardawil species related to the different phytogeographical regions of Egypt. Nd: Nile Delta, Nv: Nile Valley, Nf: Nile Faiyum, O: Oases of the Libyan desert, Mma: Western Mediterranean coast, Mp: Eastern Mediterranean coast, Da: Arabian desert, Di: Isthmic desert, Dl: Libyan desert, R: Red Sea coast, GE: Gebel Elba and surrounding mountains and S: Sinai proper.**

Table 4.2. **Distribution of the species recorded in Lake Bardawil in geographical regions of Egypt as distinguished by Täckholm (1974). cc: very common, c: common, r: rare, rr: very rare. A: Absolute value, R: relative value.**

Species	Phytogeographical region												Total	Abundance	
	Nd	Nv	Nf	O	Mm	Mp	Da	Di	Dl	R	Ge	Si		A	R(%)
Cressa critica	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	12	48	100
Cynodon dactylon	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	12	48	100
Cyperus laevigatus	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	12	48	100
Juncus rigidus	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	12	48	100
Launaea nudicaulis	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	12	48	100
Phoenix dactylifera	c	c	c	c	c	c	c	c	c	c	c	c	12	36	75
Tamarix nilotica	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc	12	48	100
Frankenia pulverulenta	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc		cc	11	44	92
Malva parviflora	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc		cc	11	44	92
Nitraria retusa	cc	cc		cc	cc	cc	cc	cc	cc	cc	cc	cc	11	44	92
Phragmites australis	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc		cc	11	44	92
Reichardia tingitana	cc	cc	cc		cc	cc	cc	cc	cc	cc	cc	cc	11	44	92
Soncuhs oleraceous	cc	cc	cc	cc	cc	cc	cc	cc	cc	cc		cc	11	44	92
Cistanche phelypaca	c	c		c	c	c	c	c	c	c		c	10	30	63
Haplophyllum tuberculatum		cc		cc	cc	cc	cc	cc	cc	cc	cc	cc	10	40	83
Launaca capitata	cc			cc	cc	cc	cc	cc	cc	cc	cc	cc	10	40	83
Panicum turgidum	cc	cc		cc		cc	cc	cc	cc	cc	cc	cc	10	40	83
Schismus arabicus	cc	cc		cc	cc	cc	cc	cc	cc	cc		cc	10	40	83
Stipa capensis	cc	cc			cc	cc	cc	cc	cc	cc	cc	cc	10	40	83
Avena barbata	cc	cc		cc	cc	cc	cc	cc	cc			cc	9	36	75
Centropodia forsskaolii	cc			cc	cc	cc	cc	cc	cc	cc		cc	9	27	56
Dipcadi erythraeum	c			c	c	c	c	c	c	c		c	9	36	75
Neurada procumbens				c	c	c	c	c	c	c	c	c	9	36	75
Brachypodium distachyum	c		c	c	c	c		c			c	c	8	24	50
Brassica tournefortii	cc	cc	cc	cc	cc	cc		cc				cc	8	32	67
Bupleurum semicompositum	c	c	c		c	c		c	c			c	8	24	50
Cutandia memphitica				cc	cc	cc	cc	cc	cc	cc		cc	8	32	67
Deverra tortuosa				cc	cc	cc	cc	cc	cc	cc		cc	8	32	67
Echinops spinosus					cc	cc	cc	cc	cc	cc	cc	cc	8	32	67
Eremobium aegyptiacum	cc	cc				cc	cc	cc	cc	cc		cc	8	32	67
Iflago spicata					c	c	c	c	c	c	c	c	8	24	50
Lotus halophilus	cc		cc	cc	cc	cc	cc	cc	cc				8	24	50
Senecio glaucus spp. *Glaucus*					c	c	c	rr	c	c		c	8	13	27
Tamarix amplexicaulis	c	c	c	c			c	c	c	c			8	24	50
Zygophyllum album				cc	cc	cc	cc	cc	cc	cc		cc	8	32	67
Anabasis 100rabica100ca				cc	cc	cc	cc	cc	cc			cc	7	28	58
Arthrocnemum macrostachyum	c			c	c	c		c		c		c	7	21	44
Atractylis carduus					c	c	c	c	c		c	c	7	21	44
Bassia muricata				cc	cc	cc	cc	cc	cc			cc	7	28	58
Cleome amblyocarpa						cc	cc	cc	cc	cc	cc	cc	7	28	58
Cyperus conglomeratus	c				c	c	c	c	c			c	7	21	44
Filago desertorum					cc	cc	cc	cc	cc	cc		cc	7	28	58
Mesembryanthemum forsskalii				c	c	c	c	c	c			c	7	21	44
Plantago ovata	cc				cc	cc	cc	cc	cc			cc	7	28	58
Polycarpon succulentum		cc			cc	cc	cc	cc	cc			cc	7	28	58
Stipagrostis 100rabica					c	c	c	c	c		c	c	7	21	44
Suaeda aegyptiaca	cc		cc	cc	cc	cc	cc	cc					7	28	58
Suaeda vera	c				c	c	c			c	c	c	7	21	44
Trigonella stellata			c		c	c	c	c	c	c			7	21	44
Anchusa humilis			c	c	c	c		c				c	6	18	38
Artemisia monosperma					cc	cc	cc	cc	cc			cc	6	24	50
Bromus rubens				r	c	c		r	r			r	6	14	29

Centauria calcitrapa	cc	cc	cc	cc	cc	cc							6	24	50
Convolvulus lanatus					cc	cc	cc	cc	cc			cc	6	24	50
Cornulaca monacantha					c		c	c	c	c		c	6	18	38
Cotula cinerea					cc		cc	cc	cc	cc		cc	6	24	50
Echiochilon fruticosum					c	c	c	c	c			c	6	18	38
Ephedra alata				c		c	c	c	c			c	6	18	38
Erodium laciniatum					r	r	r	r	r			r	6	12	25
Gymncarpos decandrus					cc	cc	cc	cc	cc			cc	6	24	50
Heliotropium digynum						cc	cc	cc	cc	cc		cc	6	18	38
Linaria haelava					c	c	c	c	c			c	6	18	38
Lycium shawii					cc		cc	cc		cc	cc	cc	6	18	38
Moltkiopsis 101rabica					c	c	c	c	c			c	6	18	38
Plantago 101rabica101cal					c	c	c	c	c			c	6	24	50
Polycarpaea repens						cc	cc	cc	cc		cc	cc	6	18	38
Retama raetum					cc	cc	cc	cc	cc			cc	6	18	38
Salvia lanigera					c	c	c	c	c			c	6	18	38
Sarcocornia fruticosa	c		c	c	c	c		c					6	12	25
Stipagrostis scoparia	c			c		c	c	c	c				6	18	38
Asparagus stipularis				cc	cc	cc		cc				cc	5	20	42
Echium angustifolium					c	c		c	c			c	5	20	42
Halocnemum strobilaceum					c	cc		c		c		c	5	16	33
Haloxylon scoparium					r	r		r	r			r	5	10	21
Helianthimum stipulatum					c	c	c	c				c	5	15	31
Herniaria 101rabica				c	c	c	c	c					5	15	31
Limonium pruinosum					cc	cc	cc	cc				cc	5	20	42
Ononis serrata					c	c	c	c				c	5	15	31
Paronychia 101rabica		c			c	r	r		c				5	13	27
Peganum harmala					c	c	c	c				c	5	15	31
Poa annua	c	c	c		c		c						5	12	25
Salicornia europaea	c		c	c	c	c							5	15	31
Salsola kali	c				c	c		c				c	5	15	31
Spergularia marina	cc	cc	cc		cc	cc							5	20	42
Thymelaca hirsuta				cc	cc	cc		cc	cc				5	15	31
Traganum nudatum				c			c	c	c			c	5	20	42
Adonis dentata					cc	cc		cc	cc				4	16	33
Aegilops kotschyi				c	c	c		c					4	12	25
Argyrolobium uniflorum					r	r		r	r			r	4	8	17
Asphodelus viscidulus					r	r		r				r	4	8	17
Astragalus annularis					c	c		c				c	4	12	25
Cakile maritima	c			c	c		c						4	12	25
Crucianella membranacea	r					r		r				r	4	8	17
Erucaria hispanica					c	c		c				c	4	12	25
Euphorbia granulata							cc	cc	cc		cc		4	16	33
Fagonia arabica				cc		cc	cc		cc				4	16	33
Frankenia hirsuta				c	c	c		c					4	12	25
Herniaria hemistemon					cc	cc	cc	cc					4	16	33
Hippocrepis areolata					cc	cc		cc				cc	4	16	33
Mesembryanthemum crystallinum	r				c	c	r						4	10	21
Noaca mucronata					c	c	c	c					4	12	25
Orobanche cernnua		r			r		r					r	4	8	17
Paronychia argentea					r	r		r			r		4	8	17
Silene villosa	r	r			r							r	4	8	17
Stipagrostis plumosa							c	c	c			c	4	12	25
Suaeda maritima	c				c	c	c						4	12	25
Zygophyllum aegyptium	rr				rr	rr						rr	4	4	8
Astragalus boeticus					c	c		c					3	9	19
Astragalus fruticosus					r	r		r					3	6	13
Astragalus kahiricus						r	r	r					3	6	13

Cutandia dichotoma					cc	cc		r					3	10	21
Halodule uninervis							cc			cc		cc	3	12	25
Lobularia arabica					c	c		c					3	9	19
Mesembryanthemum nodiflorum	r				c	c							3	8	17
Rumex pictus					c	c		c					3	9	19
Salsola tetragona				rr			rr		rr				3	3	6
Zygophyllum coccineum							cc	r		cc			3	10	21
Allium curtum					r	r							2	4	8
Allium papillare						r		r					2	4	8
Astragalus camelorum						rr		rr					2	2	4
Biarum olivieri					r	r							2	4	8
Bromus lanceolata	r	r											2	4	8
Cymodocea nodosa					c	c							2	6	13
Iris mariae						r		r					2	4	8
Launaea fragilis					c	c							2	4	8
Limoniastrum monopetalum					c	c							2	4	8
Muscari bicolor					rr	rr							2	4	8
Pancratium maritimum					c	c							2	4	8
Pancratium sickenbergeri						r			r				2	6	13
Ruppia cirrhosa					rr	rr							2	2	4
Bellevalia salah-eidii					rr								1	1	2
Calligonum polygonoides								rr					1	2	4
Cistanche salsa												c	1	1	2
Daucus littoralis var. littoralis						rr							1	3	6
Plantago albicans						rr							1	1	2
Solanum elaeagnifolium						r							1	2	4
Total species	**47**	**31**	**25**	**49**	**109**	**118**	**83**	**105**	**73**	**42**	**25**	**85**	**136**		
Percentage	**34.6**	**22.8**	**18.4**	**36**	**80.1**	**86.8**	**61**	**77.2**	**53.7**	**30.9**	**18.4**	**62.5**	**100**		

Twenty-eight species are very common (20.6% of the total recorded species), while 58 are common (42.6%). On the other hand, 33 species are rare (24.3%) and 17 are very rare (12.5%) (Fig. 4.6). These results indicate that many species are threatened.

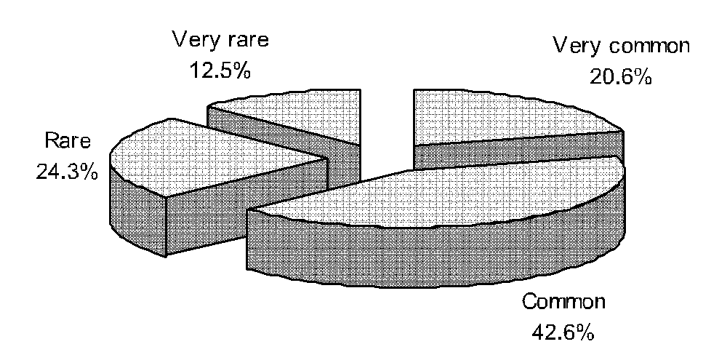


***Fig. 4.6.* Abundance categories of the species recorded in Lake Bardawil.**

According to the IUCN Red List categories (El-Hadidi & Hosny 2000), 6 threatened species were recorded in Lake Bardawil (Table 4.3): 4 of which are categorized as endangered (*Astragalus camelorum, Bellevalia salah-eidii,*

Biarum olivieri and *Salsola tetragona*). One species is indeterminate (*Lobularia arabica*), while another one is rare (*Iris mariae*).

Table 4.3. **Threatened species recorded in Lake Bardawil (after El-Hadidi & Hosny 2000).**

Species	Habit	Status
Astragalus camelorum Barbey	Perennial	Endangered
Bellevalia salah-eidii Taekh. & Boulos	Perennial	Endangered
Biarum olivieri Blume	Perennial	Endangered
Iris mariae Barbey	Perennial	Rare
Lobularia arabica (Boiss.) Muschl.	Annual	Indeterminate
Salsola tetragona Delile	Perennial	Endangered

4.1.4 Endemic and near endemic Species

Five species (3.7% of the total recorded species) are endemic taxa: *Zygophyllum album, Astragalus camelorum, Allium papillare, Bellevalia salah-eidii* and *Iris mariae*.

4.2 FLORISTIC CHARACTERIZATION OF THE ZONES

Four major zones were recognized in Lake Bardawil (sand bars, islets, southern shores and open water zones). The southern shores have the highest number of species (116 species: 85.3% of the total recoded species), followed by islets (107 species: 78.7% of the total recoded species), while the open water zone has only 3 species (*Cymodocea nodosa*, *Halodule uninervis* and *Ruppia cirrhosa*: Table 4.4, Fig. 4.7). *Suaeda vera* and *Zygophyllum propinquum* were recoded only in the sand bars zone. 16 species were recoded only in the islets zone (*Allium curtum, Allium papillare, Bellevalia salah-eidii, Biarum olivieri, Brachypodium distachyon, Bromus lanceolatus* , *Dipcadi erythraeum, Filago desertorum, Frankenia hirsuta, Haloxylon scoparium, Iris mariae, Opophytum forsskaolii, Plantago ovata, Poa annua, Polycarpaea repens, Stipagrostis ciliata*). On the other hand, 26 species were recorded only in the southern shores (*Aegilops kotschyi, Astragalus annularis, Astragalus boeticus, Astragalus camelorum, Cleome ambryocarpa, Cotula cinerea, Cressa cretica, Cynodon dactylon, Cyperus laevigatus, Ephedra alata, Fagonia arabica, Hippocrepis areolata, Juncus rigidus, Limoniastrum monopetalum, Linaria haelava, Mesembryanthemum frosskali, Muscari bicolor, Paronychia argenta, Peganum harmala, Phoenix dactylifera, Phragmites australis, Solanum elaeagnifolium, Sonchus oleraceus, Tamarix amplexicaulis, Tamarix nilotica, Traganum nudatum*).

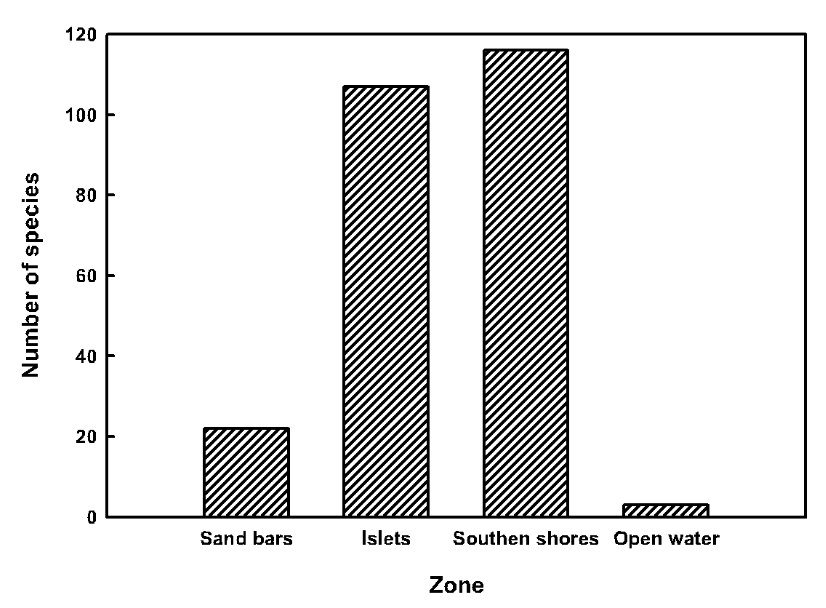


Fig. 4.7. **Distribution of the rcorded species in relation to zones of Lake Bardawil**

4.3 FLORISTIC CHARACTERIZATION OF THE HABITAT TYPES

4.3.1 Habitat Types

Six main habitats of Lake Bardawil and its surroundings have been described (Khedr & El-Gazzar 2000, El-Bana 2003):

1. **Open water:** A total of three flowering submerged sea grasses were recorded in this habitat: *Ruppia cirrhosa*, *Cymodocea nodosa* and *Halodule uninervis* (Fig 4.8). The last two species are widely distributed in the lake. El- Gazzar (undated) mentioned that *Halodule uninervis* has not been reported from the Mediterranean and seems to have traveled from the Red Sea through the Suez Canal.

Table 4.4. **Distribution of the recorded species according to the major zones of Lake Bardawil (after Khedr & El-Gazzar 2000).**

Species	Sand bars	Islets	Southern shores	Open water
Adonis dentata	+	+	+	
Anabasis articulata	+	+	+	
Arthrocnemum macrostachyum	+	+	+	
Asparagus stipularis	+	+	+	
Buplerum semicompositum	+	+	+	
Cakile maritima	+	+	+	
Cistanche phelypaea	+	+	+	
Cistanche salsa	+	+	+	
Cornulaca monacantha	+	+	+	
Cutandia dichotoma	+	+	+	
Cutandia memphetica	+	+	+	
Halocnemum strobilaceum	+	+	+	

Species	Sand bars	Islets	Southern shores	Open water
Ifloga spicata	+	+	+	
Limonium pruinosum	+	+	+	
Nitraria retusa	+	+	+	
Salicornia europaea	+	+	+	
Salsola tetragona	+	+	+	
Zygophyllum aegyptium	+	+	+	
Zygophyllum album	+	+	+	
Salsola kali	+		+	
Anchusa humilis		+	+	
Argyrolobium uniorum		+	+	
Artemisia monosperma		+	+	
Asphodelus viscidulus		+	+	
Astragalus fruticosus		+	+	
Astragalus kahiricus		+	+	
Atractylis carduus		+	+	
Avena barbata		+	+	
Bassia muricata		+	+	
Brassica tournefortii		+	+	
Bromus rubens		+	+	
Calligonum polygonoides		+	+	
Centaurea calcitrapa		+	+	
Centropodia forsskaolii		+	+	
Convolvulus lanatus		+	+	
Crucianella membrenacea		+	+	
Cyperus conglomeratus		+	+	
Daucus littoralis var. *littoralis*		+	+	
Deverra tortuosa		+	+	
Echinops spinosus		+	+	
Echiochi/on fruticosum		+	+	
Echium angustifolium		+	+	
Emex spinosus		+	+	
Eremobium aegyptiacum		+	+	
Erodium laciniatum		+	+	
Erucaria hispanica		+	+	
Euophorbia granulata		+	+	
Frankenia pulverulenta		+	+	
Gymnocarpos decandrus		+	+	
Haplophyllum tuberculatum		+	+	
Helianthemum stipulatum		+	+	
Heliotropium digynum		+	+	
Herniaria hemistemon		+	+	
Herniaria hirsuta		+	+	
Launaea capitata		+	+	
Launaea nudicaulis		+	+	
Launaea fragilis		+	+	
Lobularia arabica		+	+	
Lotus halophilus		+	+	
Lycium shawii		+	+	
Malva parviflora		+	+	

Species	Sand bars	Islets	Southern shores	Open water
Mesembryanthemum crystallinum		+	+	
Mesembryanthemum nodiflorum		+	+	
Moltkiopsis ciliata		+	+	
Neurada procumbens		+	+	
Noaea mucronata		+	+	
Ononis serrata		+	+	
Orobanche cernua		+	+	
Pancratium maritimum		+	+	
Pancratium sickenbergeri		+	+	
Panicum turgidum		+	+	
Paronychia arabica		+	+	
Plantago albicans		+	+	
Plantago cylindrica		+	+	
Polycarpon succulentum		+	+	
Reichardia tingitana		+	+	
Retama raetam		+	+	
Rumex pictus		+	+	
Salvia lanigera		+	+	
Sarcocornia fruticosa		+	+	
Schismus arabicus		+	+	
Senecio glaucus subsp. *glaucus*		+	+	
Silene villosa		+	+	
Spergularia marina		+	+	
Stipa capensis		+	+	
Stipagrostis plumosa		+	+	
Stipagrostis scoparia		+	+	
Suaeda aegyptiaca		+	+	
Suaeda maritima		+	+	
Thymelaea hirsuta		+	+	
Trigonella stellata		+	+	
Suaeda vera	+			
Zygophyllum propinquum	+			
Allium curtum		+		
Allium papillare		+		
Bellevalia salah-eidii		+		
Biarum olivieri		+		
Brachypodium distachyon		+		
Bromus lanceolatus		+		
Dipcadi erythraeum		+		
Filago desertorum		+		
Frankenia hirsuta		+		
Haloxylon scoparium		+		
Iris mariae		+		
Muscari bicolor		+		
Opophytum forsskaolii		+		
Plantago ovata		+		
Poa annua		+		
Polycarpaea repens		+		

Species	Sand bars	Islets	Southern shores	Open water
Stipagrostis ciliata		+		
Aegilops kotschyi			+	
Astragalus annularis			+	
Astragalus boeticus			+	
Astragalus camelorum			+	
Cleome ambryocarpa			+	
Cotula cinerea			+	
Cressa cretica			+	
Cynodon dactylon			+	
Cyperus laevigatus			+	
Ephedra alata			+	
Fagonia arabica			+	
Hippocrepis areolata			+	
Juncus rigidus			+	
Limoniastrum monopetalum			+	
Linaria haelava			+	
Mesembryanthemum frosskali			+	
Paronychia argenta			+	
Peganum harmala			+	
Phoenix dactylifera			+	
Phragmites australis			+	
Solanum elaeagnifolium			+	
Sonchus oleraceus			+	
Tamarix amplexicaulis			+	
Tamarix nilotica			+	
Traganum nudatum			+	
Cymodocea nodosa				+
Halodule uninervis				+
Ruppia cirrhosa				+
Total species	**22**	**107**	**116**	**3**

Gazzar (undated) mentioned that *Halodule uninervis* has not been reported from the Mediterranean and seems to have traveled from the Red Sea through the Suez Canal.

2. **Wet salt marshes:** Fourteen species were recorded in this habitat. The characteristic species of this habitat are *Halocnemum strobalaceum* and *Sarcocornia fruticosa*. The associated species include *Suaeda maritima, Frankenia pulverulenta*, *Tamarix nilotica*, *Phragmites australis*, and *Arthrocnemum macrostachyum*.

3. **Saline sand flats and hummocks (nebkas):** A total of 34 species were recorded in this habitat. *Zygophyllum album* is the characteristic species of the sand flats, while *Nitraria retusa* is the characteristic species of the sand hummocks (nabkas). The associated species include *Cutandia dichotoma, Spergularia marina, Mesembryanthemum crystallinum, Schismus barbatus, Senecio glaucus, Lotus halophilus, Zygophyllum aegyptium, Bassia muricata*, and *Salsola tetragona*.

4. **Stabilized sand dunes:** A total of 78 species were recorded in this habitat. The characteristic species of this habitat are *Stipagrostis plumosa* and *Retama raetum* in the stablized dunes of the eastern islets (e.g. El-Fasiyat and El-Mahasnah) and *Asparagus stipularis, Deverra tortusa* and *Echium angustifolium* in the western islets. Other associated species include *Schismus barbatus, Launaea capitata, Daucus litoralis, Bupleurum semicompositum, Lycium shawii, Echichilon fruticosum* and *Anabasis articulata*.

5. **Interdune depressions:** This habitat is the most diverse habitat in Lake Bardawil, because of size and level relative to groundwater, 111 species were recorded. The characteristic species of the non-saline facies of this habitat are *Panicum turgidum, Artemisia monosperma* and *Thymelaea hirsuta*. The frequent associated species are *Asphodelus viscidulus, Ononis serrata, Iflago spicata, Plantago cylindrica Pancratium maritimum, Cynodon dactylon, Atractylis carduus* and *Salvia lanigera*. In lower-level sites, salinity tolerant species prevail,

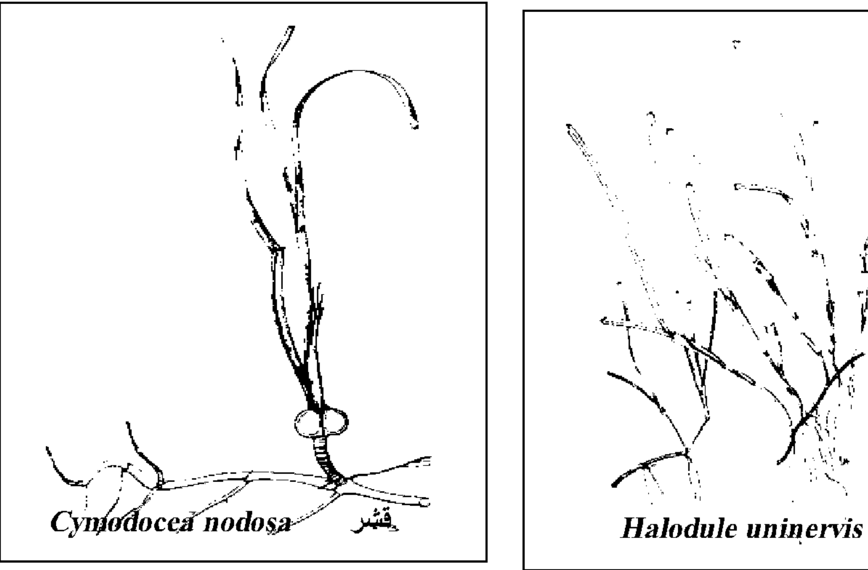
6. **Mobile sand dunes:** A total of 49 plant species were recorded in this habitat. The dominant species are *Stipagrostis scoparia* and *Calligonum polygonoides*. The associated species include *Lotus halophilus, Ermobium aegyptiacum, Silene villosa, Malva parviflora, Artemisia monosperma, Retama raetum, Cornulaca monocantha, Pancratium sickenbergeri* and *Heliotropium digynum*.

4.3.2 Similarity Between Diverse Habitats

The highest floristic similarity (Sørensen 1948) was between the stabilized sand dunes and interdune depressions (0.34%). On the other hand, there is a low floristic similarity between these habitats on one hand and the open water and salt marsh zones on the other hand (Table 4.5). This indicates gradual species compositional changes throughout the sand formations in contrast with the open water and salt marshes. Similar conclusions have been made by El-Sheikh (1989), Shaltout & El-Halawany (1993) and Al-Sodany (1998).

Table 4.5. **Matrix of Sørensen similarity coefficients, calculated between each pair of plant assemblages of the six habitats of Lake Bardawil. The maximum and minimum values are underlined.**

Habitat	*OW*	*SM*	*SH*	*SD*	*ID*	*MD*
Open water (OW)						
Wet salt marshes (SM)	*0.12*					
Saline sand flats and hummocks (SH)	*0.00*	*0.13*				
Stablized sand dunes (SD)	*0.00*	*0.00*	*0.18*			
Interdunes depressions (ID)	*0.00*	*0.00*	*0.06*	*0.34*		
Mobile sand dunes (MD)	*0.00*	*0.00*	*0.19*	*0.13*	*0.132*	



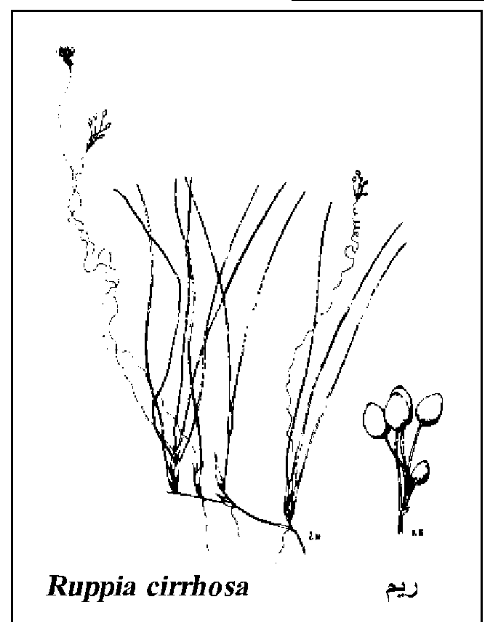


Fig. 4.8. **The three sea grasses distributed in the open water zone of Lake Bardawil (after Feinbrun-Dothan 1986).**

The application of the agglomerative clustering technique on the plant assemblaged of the 6 habitats (Fig. 4.9) and the similarity ordination (Fig. 4.10) indicate a distinction of 4 clusters. Cluster A includes communities of stabilized sand dunes and interdunes depressions, cluster B includes community of saline sand flats and hummocks, cluster C includes communities of open water and wet salt marshes and cluster D includes community of mobile sand dunes. This ordination reflects differences in the moisture status between these habitats. Similar conclusion was made by Al-Sodany (1998).

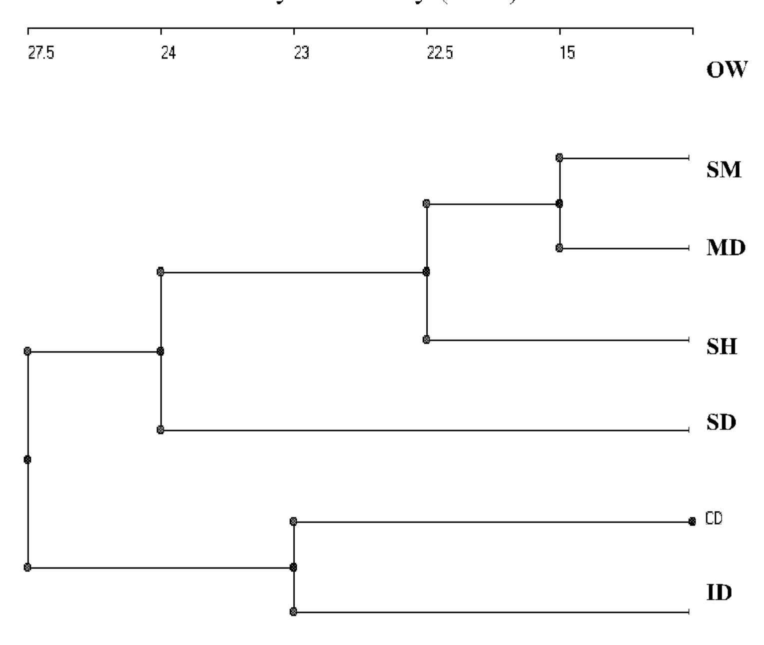


Fig. 4.9. **The dendrogram resulting from the application of the agglomerative clustering technique on floristic composition of the six habitats of Lake Bardawil. OW: open water, SM: wet salt marshes, SH: sand flats and hummocks, MD: mobile sand dunes, SD: Stabilized sand dunes, and ID: Interdunes depressions.**

4.4 VEGETATION ANALYSIS

4.4.1 Vegetation Groups

The application of TWINSPAN on the cover estimates of 45 species recorded in 150 stands in Lake Bardawil (after El-Bana 2003) led to the recognition of nine vegetation groups (Fig. 4.11). The application of DCA on the same set of data indicates a reasonable segregation among these groups along the ordination plane of axes 1 and 2 (Fig. 4.12). The following is a brief description of these vegetation groups (Tables 4.6 & 4.7).

1. *Ruppia cirrhosa-Cymodocea nodosa* group. It comprises 10 stands and three species. This group contains the stands of the benthic sea grasses along the coast and around the fringes of the islets of the lake. *Ruppia cirrhosa* (P= 80%) dominates the eastern coast of the lake, while *Cymodocea nodosa* (P= 70%) is dominant on the western coast of the lake. *Halodule uninervis* is recorded as an associated species near the lake-sea connections.

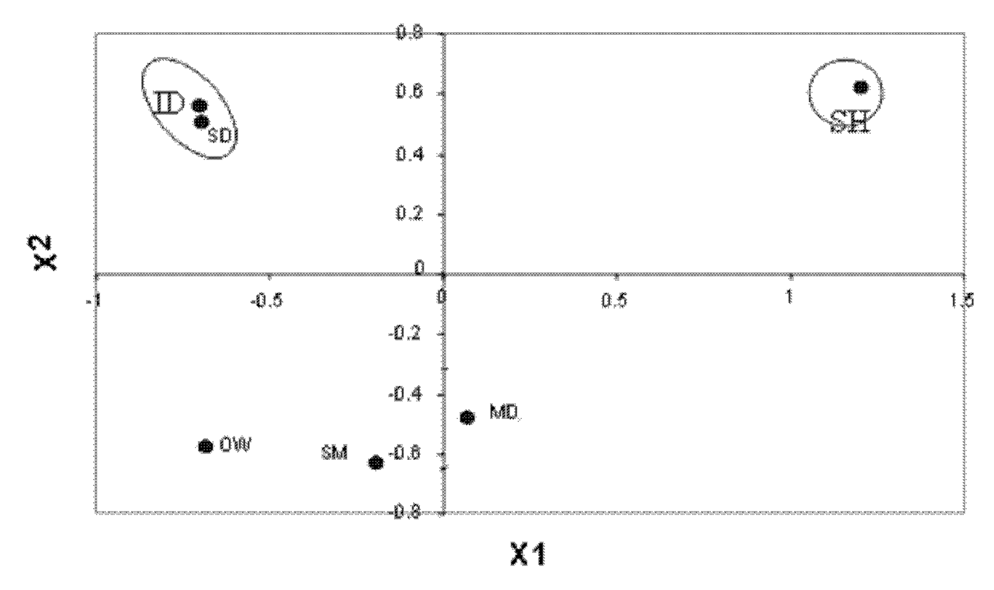


Fig. 4.10. **Similarity ordination based on the floristic composition of the six habitats of Lake Bardawil.**

2. *Halocnemum strobilaceum* group. It comprises 15 stands and 8 species. All stands of this group were from the wet salt marshes of the lake shorelines, the wet sabkhas and the shores of islets. These habitats are periodically inundated by seawater. The species of this community are mainly halophytes. The dominant species are *Halocnemum strobilaceum* (P= 100%) and *Sarcocornia fruticosa* (P= 87%). On some sabkhas, there is a belt of *Halocnemum strobilaceum* forming nearly pure stands containing a few plants of *Arthrocnemum macrostachyum* and *Zygophyllum album*. The common species on the lake shorelines are *Cutandia dichotoma*, *Cakile maritima* and *Spergularia marina*.

3. *Zygophyllum album* group. It comprises 20 stands and 12 species. This group is located on the salty sand plains of the islets and around the sabkhas. *Zygophyllum album* (P= 100%) is the characteristic species for this vegetation group, which is rarely flooded by lake water. Among the associated species are: *Arthrocnemum macrostachyum*, *Suaeda vera*, *Halocnemum strobilaceum*, *Mesembryanthemum crystallinum* and *Frankenia pulverulenta*.

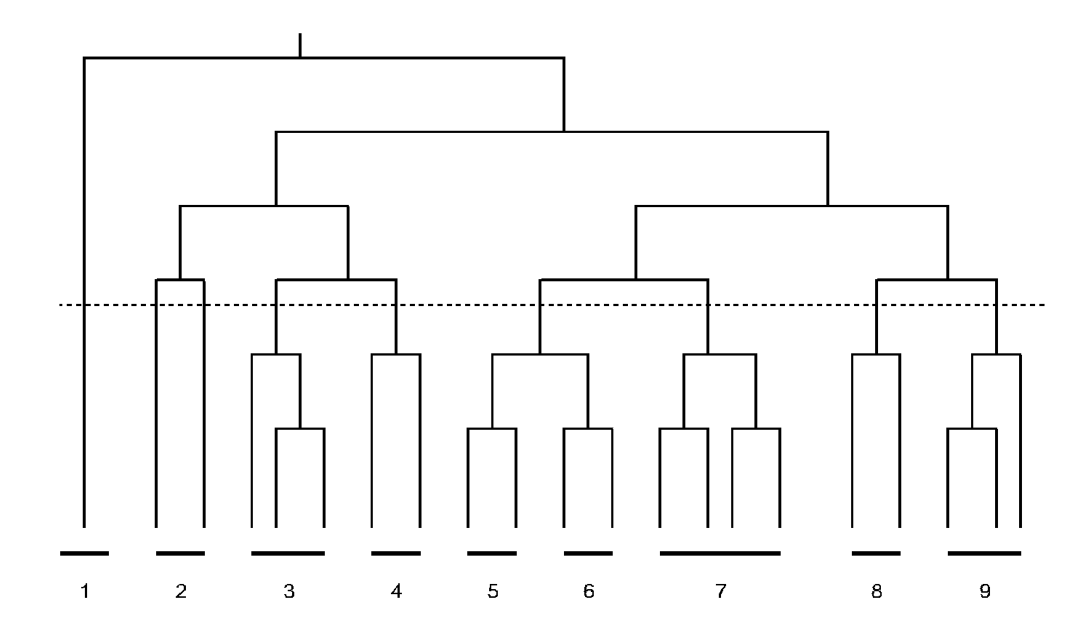


Fig. 4.11. **The dendrogram resulting from the application of TWINSPAN on the 150 sampled stands in Lake Bardawil. The names of these groups are: 1: *Ruppia cirrhosa-Cymodocea nodosa,* 2: *Halocnemum strobilaceum,* 3: *Zygophyllum album,* 4: *Nitraria retusa,* 5: *Stipagrostis plumosa-Retama raetum,* 6: *Panicum turgidum-Thymelaea hirsuta,* 7: *Artemisia monosperma,* 8: *Asparagus stipularis* and 9: *Stipagrostis scoparia-Calligonum plygonoides* (after El-Bana 2003).**

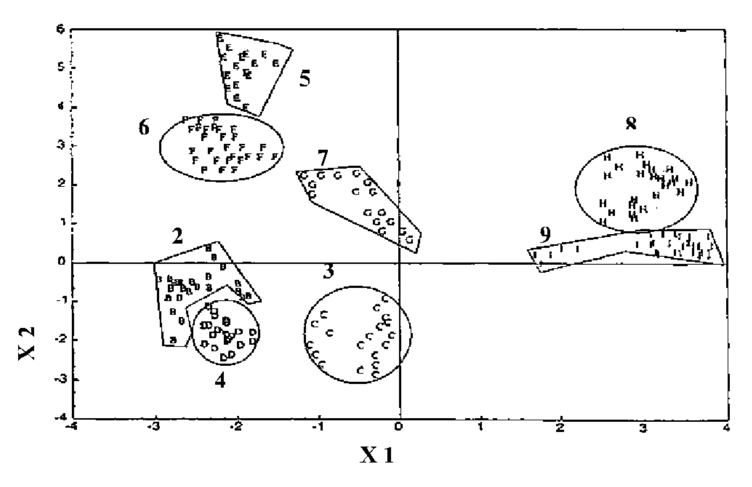


Fig. 4.12. **DCA ordination of the 150 sampled stands in Lake Bardawil (after El-Bana 2003).**

4. *Nitraria retusa* group. It comprises 15 stands and 11 species. This plant community is dominated by the xerophytic spiny salt shrub *Nitraria retusa* (P= 100%). Goats and Camels heavily graze this species up to a height where its branches become rigid and spinescent. This community is widespread throughout the lake particularly in the western section. *Zygophyllum aegyptium, Cressa cretica, Juncus rigidus* and *Tamarix nilotica* grow between the widely spaced hummocks of *Nitraria retusa*.

5. *Stipagrostis plumosa-Retama raetum* group. It comprises 15 stands and 21 species. This group comprises the stands of the stabilized dunes in the eastern islets (El-Fusiyat and EL-Mahasnah). It is dominated by *Stipagrostis plumosa* (P= 93%) and *Retama raetum* (P= 100%). Associated species are *Pancratium maritimum, Atractylis carduus, Iflago spicata, Ononis serrata* and *Bupleurum semicompositium* (see El-Bana *et al.* 2002, 2003).

6. *Panicum turgidum-Thymelaea hirsuta* group. It comprises 20 stands and 19 species. This group comprises sand flats and interdunes and dominated by *Panicum turgidum* (P= 90%) and *Thymelaea hirsuta* (P= 100%). It is interesting to mention that in the protected islets like El-Kals and El-Fusiyat, *Panicum turgidum* predominates the community and the evergreen unpalatable shrub *Thymelaea hirsuta* looks dry.

***Table 4.6.* Characteristics of the 9 vegetation groups derived after the application of TWINSPAN on the 150 sampled stands in Lake Bardawil.**

VG	N	G/P	NS	Habitat	First dominant species	P (%)	second dominant species	P (%)
1	10	6.7	3	Open water	*Ruppia cirrhosa*	80	*Cymodocca nodosa*	70
2	15	10	8	Wet salt marshes	*Halocnemum strobilaceum*	100	*Sarcocornia fruticosa*	87
3	20	13	12	Sand plains	*Zygophyllum album*	100	*Halocnemum strobilaceum*	85
4	15	10	11	Sand sheets and nebkhas	*Nitraria retusa*	100	*Arthrocnemum macrostachyum*	75
5	15	10	21	Stabilized sand dunes	*Retama raetum*	100	*Stipagrostis plumosa*	93
6	20	13	19	Sand flats and iterdunes	*Thymelaea hirsuta*	100	*Panicum turgidum*	90
7	15	10	24	Sand flats and iterdunes	*Artemisia monosperma*	100	*Moltkiopsis ciliata*	87
8	18	12	21	Stabilized sand dunes	*Asparagus stipularis*	100	*Deverra tortuosa*	89
9	22	15	9	Mobilized sand dunes	*Stipagrostis scoparia*	82	*Calligonum polygonoides*	82

VG: vegetation group, N: number of stands, G/P: the percentage of the stands of each vegetation group in relation to the total number of stands, NS: number of species per group, P: presence of species.

7. *Artemisia monosperma* group. It comprises 15 stands and 24 species. This group contains much richer assemblages, many are restricted to interdunes but include some species usually found in partially stabilized dunes of the lake islets. *Artemisia monosperma* (P= 100%) and *Moltkiopsis ciliata* (P= 87%) are the indicator species for partially stabilized dunes, while *Artemisia monosperma* and *Thymelaea hirsuta* are characteristic species for the interdunes. The

associated species are *Noaea mucronata*, *Panicum turgidum*, *Pancratium sickenbergeri*, *Neurada procumbens* and *Schismus barbatus*.

Table 4.7. **Presence percentage of the indicator and preferential species resulting from the application of TWINSPAN classification on the 150 sampled stands in Lake Bardawil (El-Bana 2003 with modification).**

Vegetation group	1	2	3	4	5	6	7	8	9	P (%)
No. of stands	10	15	20	15	15	20	15	18	22	
Species										
Cymodocea nodosa	70									11.1
Halodule uninervis	20									11.1
Ruppia cirrhosa	80									11.1
Suaeda vera		67	40							22.2
Frankenia hirsuta		33	50	20						33.3
Halocnemum strobilaceum		100	85	10						33.3
Juncus rigidus		47	50	60						33.3
Limoniastrum monopetalum		33	55	40						33.3
Sarcocornia fruticosa		87	25	20						33.3
Zygophyllum aegyptium		47	60	73						33.3
Cressa critica			50	73						22.2
Nitraria retusa			30	100						22.2
Tamarix nilotica			20	47						22.2
Arthrocnemum macrostachyum			40	75	27					33.3
Anabasis articulata					47	40				22.2
Herniaria hemistemon					53	45	47			33.3
Stipagrostis plumosa					93	50	33			33.3
Artemisia monosperma					53	55	100	39		44.4
Cornulaca monacantha					33	40	60	28		44.4
Echiochilon fruticosum					33	45	40	50		44.4
Echium angustifolium					27	40	60	67		44.4
Gymncarpos decandrus					26	40	33	56		44.4
Helianthimum stipulatum					40	50	46	56		44.4
Lycium shawii					27	55	50	45		44.4
Noaea mucronata					33	45	33	56		44.4
Pancratium maritimum					67	60	33	28		44.4
Pancratium sickenbergeri					73	55	40	33		44.4
Panicum turgidum					67	90	20	22		44.4
Retama raetum					100	60	33	22		44.4
Thymelaea hirsuta					67	100	60	22		44.4
Asparagus stipularis					27	35	40	100	14	55.5
Moltkiopsis ciliata					33	45	87	50	41	55.5
Bupleurum semicompositum					20		20			22.2
Deverra tortuosa							46	89		22.2
Convolvulus lanatus							47	67	18	33.3
Cyperus conglomeratus							20	61	68	33.3
Haplophyllum tuberculatum							27	44	14	33.3
Calligonum polygonoides							28		82	22.2
Heliotropium digynum								22	73	22.2
Stipagrostis scoparia								28	82	22.2
Astragalus fruticosus									77	11.1
Zygophyllum album		53	100	33	20	15	28			66.6
Total	**3**	**8**	**12**	**11**	**21**	**19**	**24**	**21**	**9**	

8. *Asparagus stipularis* group. It comprises 18 stands and 22 species. This group was mostly located on the stabilized dunes of the western islets, dominated by *Asparagus stipularis* (P= 100%) and codominated by *Devera tortusa* (P= 89%) and *Echium angustifolium* (P= 67%). Other associated species are *Lycium shawii, Helianthemum stipulatum, Plantago cylindrica* and *Erodium laciniatum.*

9. *Stipagrostis scoparia-Calligonum polygonoides* group. It comprises 22 stands and nine species. This group dominates the mobile dunes at shorelines of El-Rumiyat islets and El-Rouaq Peninsula on the western side of the lake. It is characterized by the dominance of *Stipagrostis scoparia* and *Calligonum polygonoides* (P= 82% for each). This community is highly eroded by wind, which is indicated by ripple marks. *Astragalus fruticosus, Heliotropium digynum, Cyperus conglomeratus, Eremobium aegyptiacum* and *Neurada procumbens* are associated species.

The classification and ordination analyses suggest that the vegetation of Lake Bardawil can be divided into four main types: i- submerged sea grasses (group 1), occupying the bottom of the lake, ii- salt marshes and sabkhas (groups 2, 3 and 4), occurring along the shorelines and the bases of the islets and peninsulas, iii- calcareous dunes (groups 5, 6 and 7), located on the eastern and middle islets of the lake, and iv- non-calcareous dunes (groups 8 and 9), occurring on the western islets and peninsulas. *Ruppia cirrhosa* and *Cymodocea nodosa* are dominant sea grasses inhabiting the shallow lake water. *Ruppia cirrhosa* is apparently the only indigenous sea grass in Lake Bardawil (Lipkin 1977). *Cymodocea nodosa* could be attributed to the continuous migration from Mediterranean Sea. *Halodule uninervis* seems to have traveled from the Red Sea through Suez Canal (El-Gazzar, undated, El-Bana 2003).

Five vegetation types represent the islet dune vegetation of Lake Bardawil. Most of the characteristic species of these dunes are psammoxerophytes which tolerate extreme edaphic and climatic conditions prevailing in the study lake (El-Bana 2003). Vegetation types of groups E and F characterized by *Stipagrostis plumosa-Retama raetam* and *Panicum turgidum-Thymelaea hirsuta* mainly occupy the stabilized calcareous dunes of the eastern and middle protected islets. Comparable communities were reported in the stabilized inland sand dunes on the isthmic desert mountains and wadis (Kassas 1955, Danin 1983). *Artemisia monosperma, Moltikiopsis ciliata* and *Thymelaea hirsuta* groups inhabit the non-saline sand flats, interdunes and partially stabilized dunes of the islets and peninsulas. *Artemisia monosperma* is one of the most important shrubs of semi-stable and stable sands in desert and non-desert areas of the Middle East. *Moltikiopsis ciliata* and *Thymelaea hirsuta* are dominants in the sand formations of the Mediterranean coast of Egypt (Zahran *et al.* 1990, Shaltout & Ayyad 1994). Vegetation groups of *Asparagus stipularis* and *Stipagrostis scoparia-Calligonum polygonoides* mainly occupy the depressions between the dunes and the dune crests of the western non-calcareous islets, respectively. According to Zahran *et al.* (1990), *Asparagus stipularis* is the characteristic species of the stabilized dune along the Mediterranean Deltaic coast. *Stipagrostis scoparia* is a perennial grass, which dominates the mobile sands of both coastal and desert dunes (Gibali 1988 and Danin 1996).

4.4.2. Vegetation and Environmental Gradient

Salinity, moisture content, calcium carbonates and disturbance are among the most important environmental factors that affect the distribution and abundance of plant species in Lake Bardawil. Salinity is highly varied from one place to another. The mean value of water salinity in aquatic habitat where *Ruppia cirrhosa* and *Cymodocea nodosa* dominate prevail is 51 ppt, in dry salt marshes it is 8.3 ppt, wet salt marshes it is 5.6 ppt and mobile sand dunes it is 0.2 ppt. The $CaCO_3$ content in the soil followed the same trend of salinity. It was relatively high in the bottom sediment of the lake (42.5%), intermediate values in the salt marshes (15.7%) and calcareous sand dunes (18.6%) and low in mobile sand dunes (1.5%). Halophytic species such as *Halocnemum strobilaceum, Zygophyllum album* and *Nitraria retusa* were recorded at high levels of electrical conductivity (EC), pH, sodium and potassium. These combinations are typical in shorelines, sabkhas and feet of the islet dunes in the lake. The psammophytic species of *Stipagrostis plumosa–Retama raetum* and *Panicum turgidum–Thymelaea hirsuta* groups are positively correlated with $CaCO_3$, total nitrogen and fine texture. The species of *Asparagus stipularis* and *Stipagrostis scoparia–Calligonum polygonoides* groups are positively correlated with the depth of water table and soil coarse texture, which implies less moisture content, cations, soil salinity and organic carbon and a very deep water table. On the other hand, *Artemisia monosperma* group indicates a wide distribution in the area and their relationship with environmental variables is not clear.

Environmental factors affecting the vegetation in Lake Bardawil are typical of those known to control halophytes and psammophytes (Ayyad & El-Ghareeb 1982, Zahran *et al.* 1990, Shaltout & El-Ghareeb 1992, El-Bana *et al.* 2002). EC, pH, Na, moisture content are among the environmental factors, which are important in affecting plant communities in the lake. It is clear that all halophytes have the ability to grow and dominate in habitats with high concentrations of cations, EC, pH and moisture content. Variation within halophytes can be explained by salinity and moisture content (Corre 1985, Winter 1990).

4.4.3 Suggested Successional Trends in Lake Bardawil

The decrease in moisture, changes in salinity and soil texture are the main factors operative in the successional process of the vegetation of Lake Bardawil, depending on the regional and local conditions of topography and landforms. The submerged sea grasses such as *Cymodocea nodosa* and *Ruppia cirrhosa* are the pioneer populations that invade the shallw saline water (Fig. 4.13).

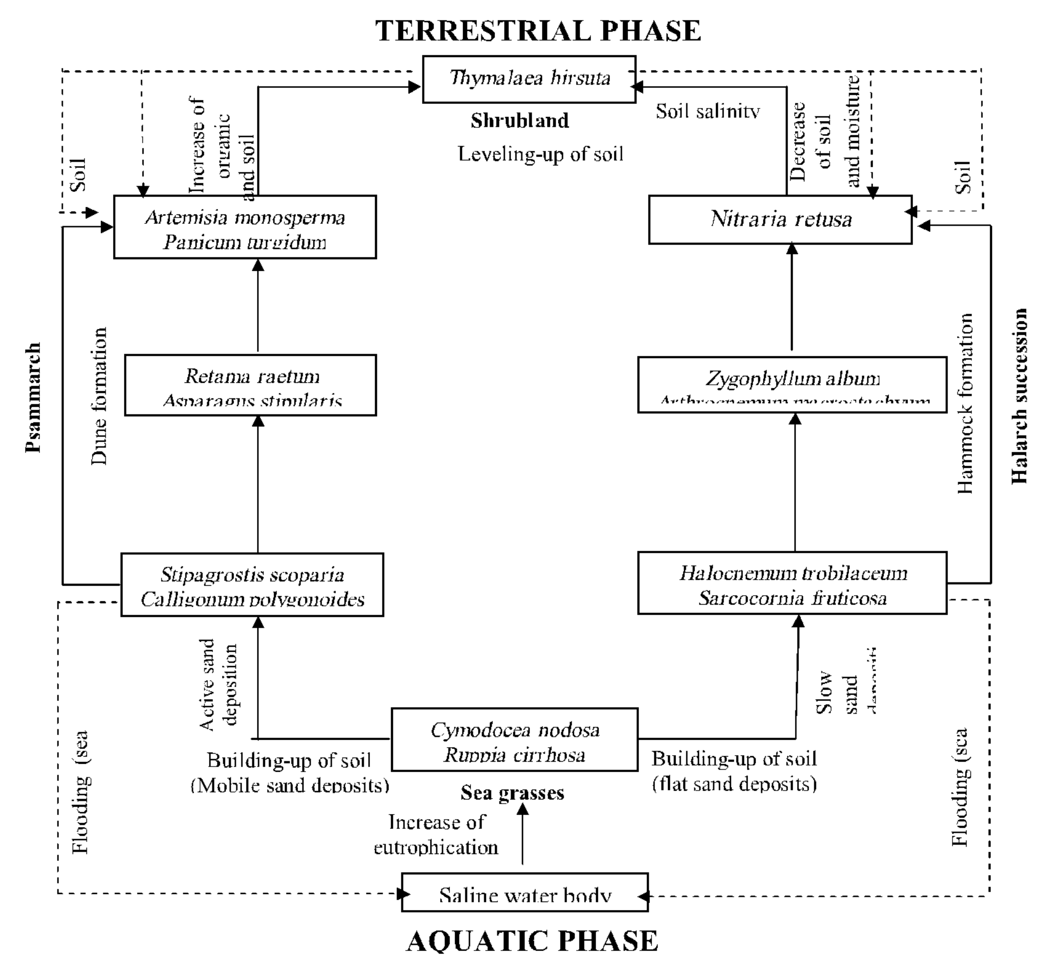


Fig. 4.13. **Schematic representation of presumed successional relationship between species dominating different habitats in Lake Bardawil.**

4.5 ENVIRONMENTAL AND ECONOMIC IMPORTANCES OF THE RECORDED SPECIES

4.5.1 Environmental Importance

Seventy seven species in Lake Bardawil (56.6% of the total recorded species) have at least one aspect of environmental importance (Table 4.8, Fig. 4.14). 55.9% of the environmentally important species are sand controllers (e.g. wind breaks, sand binders and hummock formers), followed by shaders (13.7%), segetal weeds (8.8%), ruderal weeds (7.8%) and weed controllers, parasites and nitrogen fixers (2.9%). Thirteen species (16.9% of the total important species) have three estimates of environmental importance such as: *Tamarix nilotica* (shader, ruderal and sand controller), *Arthrocnemum macrostachyum* (bank retainer, weed controller and sand controller) and

Phragmites australis (ruderal, invader and water purificator). A total of 31species (40.2% of the total important species) have two estimates of environmental importances such as: *Anabasis articulata*, *Cleome amblyocarpa* and *Retama raetum* (shader and sand controller) and *Cyprus laevigatus* (ruderals and weed controllers). A total of 33 species (42.9% of the total important species) have only one importance such as *Avena barbata* (segetal weed), *Cutandia dichotoma* (sand controller), *Juncus rigidus* (ruderal), *Suaeda vera* (bank retainer) and *Cistanche salsa* (parasite) (Fig. 4.15).

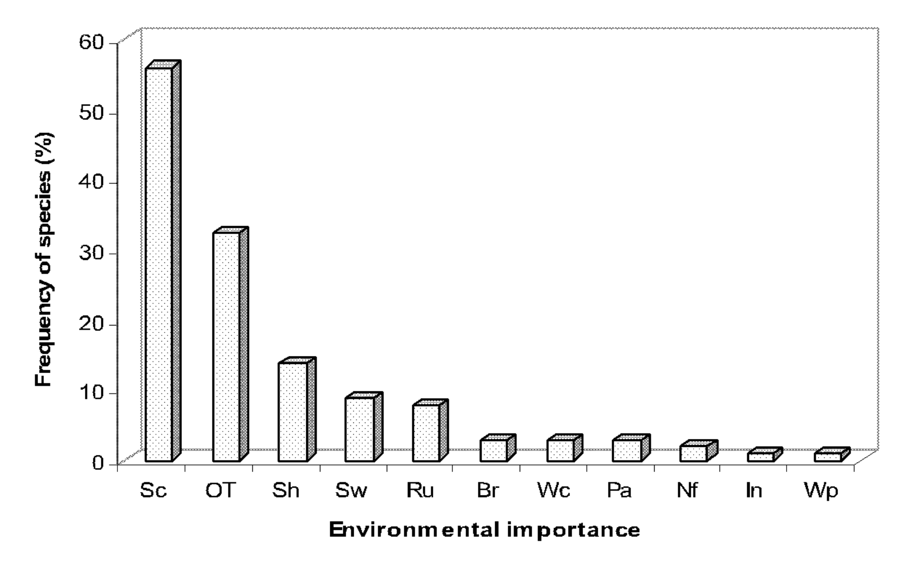


Fig. 4.14. **Descending arrangement of the environmental importance of the recorded species in Lake Bardawil. Sc: sand controllers, OT: other importances, Sh: shaders, Sw: segetal weeds, Ru: ruderals, Br: bank retainers, Wc: weed controllers, Pa: parasites, Nf: nitrogen fixer, In: water invaders and Wp: water purificators.**

Table 4.8. **Environmental importances of the species recorded in Lake Bardawil. Environmental importance is coded as follows: Br: bank retainer, Sh: shaders, Ru: ruderals, Sw: segetal weed, In: water invaders, Wc: weed controllers, Sc: sand controllers, Po: poisoners, Wp: water purificators, Nf: nitrogen fixers, Pa: parasites.**

Species	Environmental importance											Total
	Br	Sh	Ru	Sw	In	Wc	Sc	Wp	Nf	Pa	OT	
Adonis dentata		+					+				+	3
Aegilops kotschyi							+				+	2
Anabasis articulata		+					+					2
Argyrolobium uniflorum		+					+		+			3
Artemisia monosperma							+				+	2
Arthrocnemum macrostachyum	+					+	+					3
Asparagus stipularis		+					+				+	3
Asphodelus viscidulus												

Species	Environmental importance											Total
	Br	Sh	Ru	Sw	In	Wc	Sc	Wp	Nf	Pa	OT	
Astragalus annularis							+		+			2
Astragalus fruticosus												
Atractylis carduus							+				+	2
Avena barbata				+								1
Bassia muricata		+				+						2
Brassica tournefortii				+								1
Bromus rubens							+					1
Bupleurum semicompositum							+				+	2
Cakile maritima		+					+				+	3
Calligonum polygonoides			+				+					2
Centauria calcitrapa			+									1
Centropodia forsskaolii							+					1
Cistanche phelypaea							+			+		2
Cistanche salsa										+		1
Cleome amblyocarpa		+					+					2
Convolvulus lanatus		+					+				+	3
Cotula cinerea												
Cressa critica												
Crucianella membranacea												
Cutandia dichotoma							+					1
Cutandia memphitica							+					1
Cynodon dactylon				+			+					2
Cyperus conglomeratus												
Cyperus laevigatus			+			+						2
Daucus littoralis var. *littoralis*							+					1
Deverra tortuosa							+				+	2
Echinops spinosus							+				+	2
Echiochilon fruticosum							+				+	2
Ephedra alata		+					+				+	3
Euphorbia granulata							+					1
Fagonia arabica							+					1
Filago desertorum											+	1
Frankenia hirsuta							+				+	2
Gymncarpos decandrus		+					+				+	3
Halocnemum strobilaceum	+						+					2
Haloxylon scoparium												
Haplophyllum tuberculatum												
Helianthimum stipulatum							+				+	2
Heliotropium curassavicum												
Herniaria hemistemon											+	1
Iflago spicata											+	1
Iris mariae												
Juncus rigidus			+									1
Launaea capitata												
Launaea fragilis												
Launaea nudicaulis				+								1
Limoniastrum monopetalum							+				+	2
Limonium pruinosum												
Linaria haelava												
Lobularia arabica							+					1
Lotus halophilus												
Lycium shawii		+					+				+	3
Malva parviflora				+								1

Species	Environmental importance											Total
	Br	**Sh**	**Ru**	**Sw**	**In**	**Wc**	**Sc**	**Wp**	**Nf**	**Pa**	**OT**	
Moltkiopsis ciliata							+				+	2
Muscari bicolor												
Neurada procumbens												
Noaea mucronata							+				+	2
Ononis serrata							+					1
Orobanche cernnua				+						+		2
Pancratium maritimum							+				+	2
Pancratium sickenbergeri							+				+	2
Panicum turgidum							+					1
Paronychia arabica												
Paronychia argentea							+				+	2
Peganum harmala							+				+	2
Phoenix dactylifera												
Phragmites australis			+		+			+				3
Plantago albicans							+				+	2
Plantago ovata							+					1
Poa annua				+								1
Reichardia tingitana							+				+	2
Retama raetum		+					+				+	3
Rumex pictus			+									1
Salsola kali			+									1
Salsola tetragona							+				+	2
Salvia lanigera							+				+	2
Sarcocornia fruticosa							+				+	2
Schismus arabicus												
Silene villosa							+					1
Soncuhs oleraceous				+								1
Spergularia marina				+								1
Stipa capensis							+					1
Stipagrostis ciliata							+					1
Stipagrostis lanata												
Stipagrostis plumosa												
Stipagrostis scoparia							+					1
Suaeda aegyptiaca												
Suaeda vera	+											1
Tamarix nilotica		+	+				+					3
Thymelaea hirsuta		+					+				+	3
Trigonella stellata							+					1
Zygophyllum aegyptium												
Zygophyllum album							+					1
Zygophyllum coccineum												
Total species	**3**	**14**	**8**	**9**	**1**	**3**	**57**	**1**	**2**	**3**	**33**	**77**
Percentage	**2.9**	**13.7**	**7.8**	**8.8**	**1.0**	**2.9**	**55.9**	**1.0**	**2.0**	**2.9**	**32.4**	

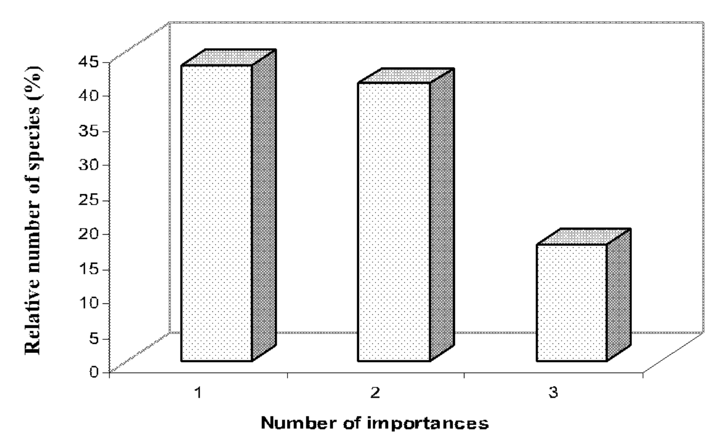


Fig. 4.15. **Frequency of the recorded species in Lake Bardawil in relation to the number of environmental importances.**

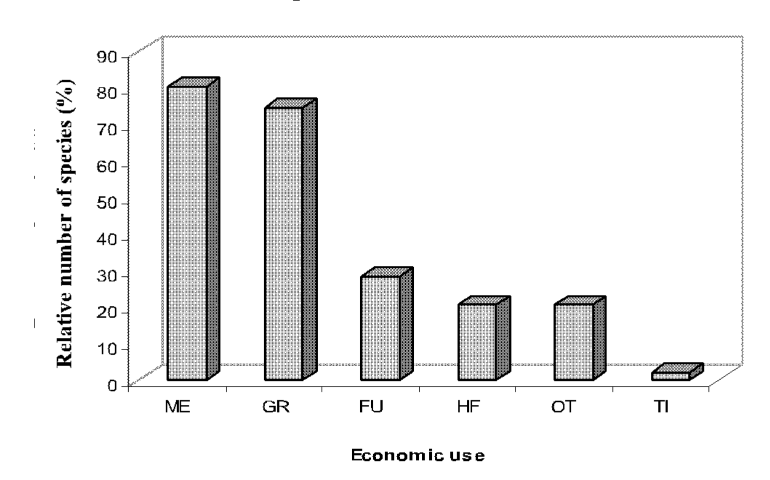


Fig. 4.16. **Descending arrangement of the economic uses of the recorded species in Lake Bardawil. ME: medicinal, GR: grazing, FU: fuel, HF: human food, OT: other uses and TI: timber.**

Sand controllers had the highest contribution of the flora of Lake Bardawil because its the predominance of sandy soils that characterize the Mediterranean coastal lands (Zahran & Willis 1992). Sand controllers are the species which seem to deal effectively with drift sand (e.g. *Panicum turgidum*, and *Artemisia monosperma*) and form dunes or hummocks (e.g. *Stipagrostis scoparia, Zygophyllum album, Retama raetum* and *Nitraria retusa*). Some species are especially useful in dealing with sand in salt marshes, such as *Juncus* species, *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum* (Simpson 1932). Most of sand controllers inhabit the sand formations and salt marshes (Ahmed 2003). The shade cast by the shading plants keeps down the

growth of weeds. Some of the bank retainers suited to salt soil such as *Arthrocnemum macrostachyum, Halocnemum strobilaceum* and *Suaeda vera*. The manner in which they retain the soil is different in the various species (Simpson 1932).

4.5.2 Economic Importance

Ninety-nine species in Lake Bardawil (72.8% of the total recorded species) have at least one aspect of the potential or actual economic uses (Table 4.9, Fig. 4.16). The domestic and wild animals may graze and browse 76 species in Lake Bardawil (76.8% of the total economic species). Among the high palatable species are *Malva parviflora, Brassica tournefortii, Cakile maritima, Cynodon dactylon* and *Trigonella stellata*. There are some examples of selective use of different plant organs at different seasons. Small branches of *Tamarix nilotica* are apparently good for camels and goats, while sheep prefer its flowers only. In addition, eighty-two species (82.8% of the total economic species) are of popular medicinal uses. For example, rhizomes of *Phragmites australis* are used as stomachic, antiemetic, antipyretic, acute arthritis, jaundice, pulmonary abscesses and diuretic (Shaltout & Al-Sodany 2000).

Fruits, flowers, vegetative and ground parts of 21 species (21.2% of the total economic species) are eaten by the inhabitants in the study area. For example fresh leaves and young shoots of *Malva parviflora* (Khubbayza) are cooked as vegetable dish. The under ground parts of *Phragmites australis* (Hagna) are sometimes eaten (Shaltout & Al-Sodany 2000).

Twenty-nine species (29.3% of the total economic species) are subjected to cutting for fuel. Local inhabitants usually use the dry parts and cut green plants when they can not find dry ones. Most of the shrubby species are cut and harvested for fuel such as *Tamarix* trees, *Arthrocnemum macrostachyum* and *Sarcocornia fruticosa* (Shaltout & Al-Sodany 2000). The timber plants are limited allover Egypt: in Lake Bardawil only two species (2% of the total economic species) are suitable as timber such as *Phoenix dactylifera* and *Tamarix* trees.

Twenty-one species (21.2% of the total economic species) are of several traditional uses. The strong fibrous culms or leaves of *Phragmites australis* are used in many parts of the world, including the area of the present study, in the weaving of mats, screens and chair bottoms, in thatching and making baskets, and in the construction of barrels and casks. *Juncus rigidus* is another species used in making mats, ropes and baskets (Shaltout & Al-Sodany 2000).

Phoenix dactylifera was the only species that had six economic uses. Three species have five uses (*Bupleurum semicompositum, Devera tortuosa* and *Phragmites australis*), 4 species have four uses (*Echinops spinosus, Calligonum polygonoides, Panicum turgidum* and *Brassica tournefortii*). 35 species have three uses such as *Aegilops kotschyi, Anabasis articulata* and *Frankenia hirsuta*

(grazing, fuel and medicinal uses), *Malva parviflora* and *Rumex pictus* and *Salsola tetragona* (grazing, medicinal and human food uses). A total of 33 species have two uses such as *Fagonia arabica* (medicinal and human food uses), *Astragalus annularis* (grazing and medicinal uses), *Limoniastrum monopetalum* (fuel and medicinal uses), *Cotula cinerea* (grazing and fuel uses) and *Sonchus oleraceous* (grazing and human food uses). In total, 23 species have only on use such as *Cutandia memphitica* and *Heliotropium curassavicum* (grazing), *Cistanche phelypaea* and *suaeda vera* (medicinal use), *Astragalus fruticosus* and *Paronychia arabica* (human food) (Fig. 4.17).

One hundred and two species (75% of the total recorded species) have, at least, one environmental and/or economic importance (Fig. 4.18). A total of 74 species have environmental and economic importances (e.g. *Adonis dentatus, Arthrocnemum macrostachyum, Bassia muricata, Cakile maritima* and *Centropodia forsskaolii*). On the other hand, three species have environmental importance only (*Cistanche salsa, Orobanche cernnua* and *Stipagrostis scoparia*), while 25 species have economic importance only (e.g. *Haplophyllum tuberculatum, Haloxylon scoparium, Stipagrostis lanata, Launaea fragilis* and *Zygophyllum aegyptium*).

Table 4.9. **Economic importances of the species recorded in Lake Bardawil. The economic importance are coded as follows GR: grazing, FU: fuel, ME: medicinal use, HF: human food, TI: timber and Ot: other uses. EI: economic index (out of 6).**

Species	Economic importance						EI
	GR	FU	ME	HF	TI	Ot	
Adonis dentata	+		+			+	3
Aegilops kotschyi	+	+	+				3
Anabasis articulata	+	+	+				3
Argyrolobium uniflorum	+	+	+				3
Artemisia monosperma	+	+	+				3
Arthrocnemum macrostachyum	+	+	+				3
Asparagus stipularis	+	+	+				3
Asphodelus viscidulus	+	+	+				3
Astragalus annularis	+		+				2
Astragalus fruticosus				+			1
Atractylis carduus	+		+				2
Avena barbata	+		+				2
Bassia muricata	+	+	+				3
Brassica tournefortii	+		+	+		+	4
Bromus rubens	+		+				2
Bupleurum semicompositum	+	+	+	+		+	5
Cakile maritima	+		+			+	3
Calligonum polygonoides	+	+	+		+		4
Centauria calcitrapa	+		+				2
Centropodia forsskaolii	+		+				2
Cistanche phelypaea			+				1
Cistanche salsa							
Cleome amblyocarpa		+	+			+	3
Convolvulus lanatus	+	+	+				3

Species	Economic importance						EI
	GR	FU	ME	HF	TI	Ot	
Cotula cinerea	+	+					2
Cressa critica		+	+				2
Crucianella membranacea			+				1
Cutandia dichotoma	+		+				2
Cutandia memphitica	+						1
Cynodon dactylon	+	+	+				3
Cyperus conglomeratus			+				1
Cyperus laevigatus	+						1
Daucus littoralis var. *littoralis*	+		+			+	3
Deverra tortuosa	+	+	+	+		+	5
Echinops spinosus	+	+	+	+			4
Echiochilon fruticosum	+			+			2
Ephedra alata			+				1
Euphorbia granulata			+				1
Fagonia arabica			+	+			2
Filago desertorum	+		+			+	3
Frankenia hirsuta	+	+	+				3
Gymncarpos decandrus	+	+	+				3
Halocnemum strobilaceum	+		+				2
Haloxylon scoparium	+		+			+	3
Haplophyllum tuberculatum			+	+		+	3
Helianthimum stipulatum	+	+	+				3
Heliotropium curassavicum	+						1
Herniaria hemistemon	+		+				2
Iflago spicata	+		+				2
Iris mariae			+				1
Juncus rigidus	+		+				3
Launaea capitata	+			+			2
Launaea fragilis	+		+				2
Launaea nudicaulis	+		+				2
Limoniastrum monopetalum		+	+				2
Limonium pruinosum	+		+				2
Linaria haelava	+						1
Lobularia arabica	+		+				2
Lotus halophilus	+		+				2
Lycium shawii	+	+	+				3
Malva parviflora	+		+	+			3
Moltkiopsis ciliata	+	+	+				3
Muscari bicolor			+				1
Neurada procumbens				+			1
Noaea mucronata	+			+			2
Ononis serrata	+		+				2
Orobanche cernnua							
Pancratium maritimum			+				1
Pancratium sickenbergeri			+				1
Panicum turgidum	+		+	+			4
Paronychia arabica				+			1
Paronychia argentea	+		+	+			3
Peganum harmala			+			+	2
Phoenix dactylifera	+	+	+	+	+	+	6
Phragmites australis	+	+	+	+		+	5
Plantago albicans	+		+				2

Species	Economic importance						EI
	GR	FU	ME	HF	TI	Ot	
Plantago ovata	+		+			+	3
Poa annua	+		+				2
Reichardia tingitana	+		+				2
Retama raetum		+	+				2
Rumex pictus	+		+	+			3
Salsola kali			+	+		+	3
Salsola tetragona	+		+	+			3
Salvia lanigera	+		+			+	3
Sarcocornia fruticosa	+	+	+				3
Schismus arabicus	+		+				2
Silene villosa			+			+	2
Soncuhs oleraceous	+			+			2
Spergularia marina	+						1
Stipa capensis	+						1
Stipagrostis ciliata	+						1
Stipagrostis lanata	+						1
Stipagrostis plumosa	+		+				2
Stipagrostis scoparia							
Suaeda aegyptiaca			+				1
Suaeda vera			+				1
Tamarix nilotica	+	+	+				3
Thymelaea hirsuta	+	+	+				3
Trigonella stellata	+		+			+	3
Zygophyllum aegyptium	+						1
Zygophyllum album	+		+			+	3
Zygophyllum coccineum	+		+				2
Total species	**76**	**29**	**82**	**21**	**2**	**21**	**99**
Percentage	**76.8**	**29.3**	**82.8**	**21.2**	**2.0**	**21.2**	

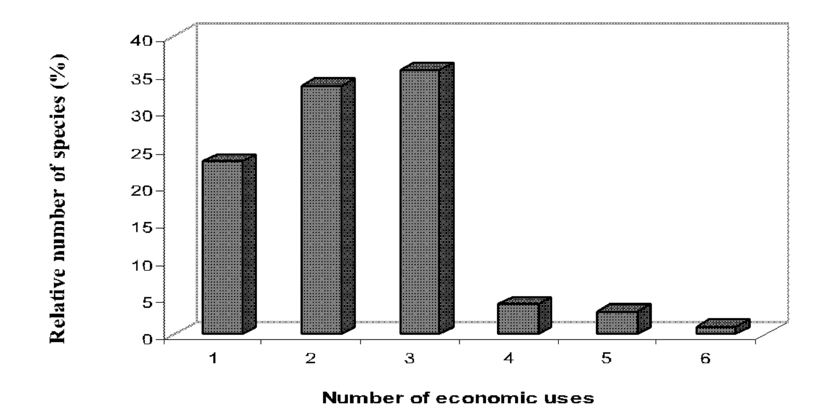


Fig.4.17. **Frequency of the recorded species in Lake Bardawil in relation to the number of economic uses.**

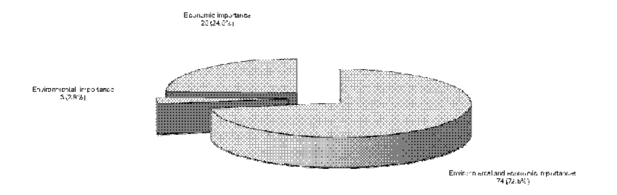


Fig 4.18. **Number and percentage of the recorded species that have environmental and/or economic importance.**

4.6 SUMMARY

A total of 136 species belonging to 109 genera and 42 families were recorded in Lake Bardawil. Gramineae had the highest contribution (12.5%) followed by Chenopodiaceae (11.0%). Sixty-nine species were recorded only in Lake Bardawil (about half of the recorded species in this lake) and not in the other northern lakes (Mariut, Edku, Burullus and Manzala), of these; 25 species are annuals and 44 species are perennials.

Seventy-nine species (58.1% of the total recorded species) are perennials, and 57 species (41.9% of the total recorded species) are annuals. On the other hand, 104 species (76.5% of the total recorded species) are natural plants, 27 (19.9%) are terrestrial weeds, 4 (2.9%) are aquatic weeds and only one species (0.7%) is escaped from cultivation. Therophytes are the most represented in Lake Bardawil, followed by chamaephytes, geophytes–helophytes, hemicryptophytes, phanerophytes, parasites and hydrophytes.

Five species are cosmopolitan. Sixty species (44.1% of the total recorded species) are mono-regionals: 42 species of which are Saharo-Arabian, 12 species are Mediterranean taxa which are Saharo-Arabian taxa penetrating other territories, 23 species are Mediterranean taxa penetrating other territories. Twenty one species are pluri-regionals: 14 species of which are Saharo-Arabian taxa penetrating other territories, 18 species are Mediterranean taxa penetrating other territories. Compared with the other northern lakes, the vegetation of Lake Bardawil has a relatively high number of endemic species (5 species).

Regarding the national distribution of species allover Egypt, 36 species have a wide national distribution (recorded in ≥ 8 out of 12 regions), of which 8 species were recorded in all the 12 regions. Twenty-eighty species are very common, while 58 are common, 33 are rare and 17 are very rare.

According to the IUCN Red List categories, 6 threatened species were recorded in Lake Bardawil: 4 of which are categorized as endangered (*Astragalus camelorum*, *Bellevalia salah-eidii*, *Biarum olivieri* and *Salsola tetragona*). One species is indeterminate (*Lobularia arabica*), while another one

is rare (*Iris mariae*). In addition, 5 species (3.7% of the total recorded species) are endemic taxa: *Zygophyllum album, Astragalus camelorum, Allium papillare, Bellevalia salah-eidii* and *Iris mariae*.

Four major zones were recognized in Lake Bardawil (sand bars, islets, southern shores and open water zones). The southern shores have the highest number of species (116 species: 85.3% of the total recoded species), followed by the islets (107 species: 78.7% of the total recoded species), while the open water zone has only 3 species (*Cymodocea nodosa, Halodule uninervis* and *Ruppia cirrhosa*)

The application of the agglomerative clustering technique on the plant assemblages of the 6 habitats and the similarity ordination indicate a distinction of 4 clusters. Cluster A includes communities of stabilized sand dunes and inter-dunes depressions, cluster B includes community of saline sand flats and hummocks, cluster C includes communities of open water and wet salt marshes and cluster D includes community of mobile sand dunes.

The application of TWINSPAN on the cover estimates of 45 species recorded in 150 stands in Lake Bardawil led to the recognition of nine vegetation groups. The application of DCA on the same set of data indicates a reasonable segregation among these groups: *Ruppia cirrhosa-Cymodocea nodosa* group, *Halocnemum strobilaceum* group, *Zygophyllum album* group, *Nitraria retusa* group, *Stipagrostis plumosa-Retama raetum* group, *Panicum turgidum-Thymelaea hirsuta* group, *Artemisia monosperma* group, *Asparagus stipularis* group and *Stipagrostis scoparia-Calligonum plygonoides* group.

Salinity, moisture content, calcium carbonates and disturbance are among the most important environmental factors that affect the distribution and abundance of plant species in Lake Bardawil. Environmental factors affecting the vegetation in Lake Bardawil are typical of those known to control halophytes and psammophytes. The decrease in moisture, changes in salinity and soil texture are the main factors operative in the successional process of the vegetation of this lake , depending on the regional and local conditions of topography and landforms.

Seventy seven species in Lake Bardawil (56.6% of the total recorded species) have at least one aspect of environmental importance. 55.9% of the environmentally important species are sand controllers (e.g. wind breaks, sand binders and hummock formers), followed by shaders (13.7%), segetal weeds (8.8%), ruderal weeds (7.8%) and weed controllers, parasites and nitrogen fixers (2.9%). In addition, 99 species in Lake Bardawil (72.8% of the total recorded species) have at least one aspect of the potential or actual economic uses. The domestic and wild animals may graze and browse 76 species in Lake Bardawil (76.8% of the total economic species). Fruits, flowers, vegetative and ground parts of 21 species (21.2% of the total economic species) are eaten by the local

inhabitants in the study area. Twenty-nine species (29.3% of the total economic species) are subjected to cutting for fuel. Local inhabitants, usually use the dry parts and cut green plants when they can not find dry ones. Most of the shrubby species are cut and harvested for fuel such as *Tamarix* trees, *Arthrocnemum macrostachyum* and *Sarcocornia fruticosa* (Shaltout & Al-Sodany 2000). The timber plants are limited allover Egypt: in Lake Bardawil only two species (2% of the total economic species) are suitable as timber such as *Phoenix dactylifera* and *Tamarix* trees. Twenty-one species (21.2% of the total economic species) are of several traditional uses.

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4.7 PLATES OF PLANTS: 4.1 – 4.21

(after Shaltout & Al-Sodany* and The Jerusalem Botanical Gardens**: www.botanic.co.il)

Plate 4.1
*Calligonum polygonoides**
*Rumex pictus***
*Mesembryanthemum crystallinum***
*Mesembryanthemum nodiflorum***
*Gymncarpos decandrus**
*Herniaria hemistemon***

Plate4.2
*Herniaria hirsuta***
*Paronychia arabica***
*Paronychia argentea***
*Polycarpaea repens***

Plate 4.3
*Anabasis articulata**
*Arthrocnemum macrostachyum***
*Halocnemum strobilaccum**
*Cornulaca monacantha**
*Noaea mucronata***
*Salicornia europaea***

Plate 4.4
*Bassia muricata**
*Haloxylon scoparium***
*Suaeda aegyptiaca***
*Salsola kali***

Plate 4.5
*Suaeda vera***
*Cleome amblyocarpa***
*Eremobium aegyptiacum***
Erucaria hispanica **

Plate 4.6
*Salsola tetragona**
Adonis dentata *
*Brassica tournefortii***
*Cakile maritima***
*Neurada procumbens***
*Acacia saligna**

Plate 4.7
*Argyrolobium uniflorum***
*Astragalus annularis***
*Astragalus boeticus***
*Astragalus kahiricus**

Plate 4.8
*Hippocrepis areolata***
*Lotus halophilus***
*Ononis serrata***
*Malva parviflora***

Plate 4.9
Retama raetum *
*Trigonella stellata**
*Erodium laciniatum***
*Fagonia arabica**
Peganum harmala **
*Zygophyllum album**

Plate 4.10
*Zygophyllum coccineum**
*Nitraria retusa**
*Haplophyllum tuberculatum**
*Thymelaea hirsuta**
*Helianthimum stipulatum**
*Cynomorium coccineum**

Plate 4.11
*Tamarix nilotica***
*Frankenia pulverulenta***
*Limonium pruinosum**
*Convolvulus lanatus**
*Anchusa humilis**
*Echiochilon fruticosum**

Plate 4.12
*Frankenia hirsuta***
*Deverra tortuosa***
*Echium angustifolium***
*Heliotropium digynum***

Plate 4.13
*Moltkiopsis ciliata**
*Salvia lanigera***
*Lycium shawii**
*Cistanche phelypaea**
*Cistanche salsa***
*Plantago ovata***

Plate 4.14
*Solanum elaeagnifolium***
*Linaria haelava***
*Orobanche cernnua***
*Plantago albicans**

Plate 4.15
*Plantago cylindrica***
*Reichardia tingitana***
*Artemisia monosperma**
*Soncuhs oleraceous***

Plate 4.16
*Atractylis carduus**
*Filago desertorum***
*Iflago spicata***
*Launaea fragilis***
*Launaea nudicaulis***
Senecio glaucus spp. *glaucus***

Plate 4.17
*Ruppia cirrhosa**
*Asparagus stipularis**
*Pancratium maritimum**
*Pancratium sickenbergeri**
*Cutandia memphitica***
*Cynodon dactylon***

Plate 4.18
*Dipcadi erythraeum***
*Iris mariae***
*Aegilops kotschyi***
*Avena barbata***

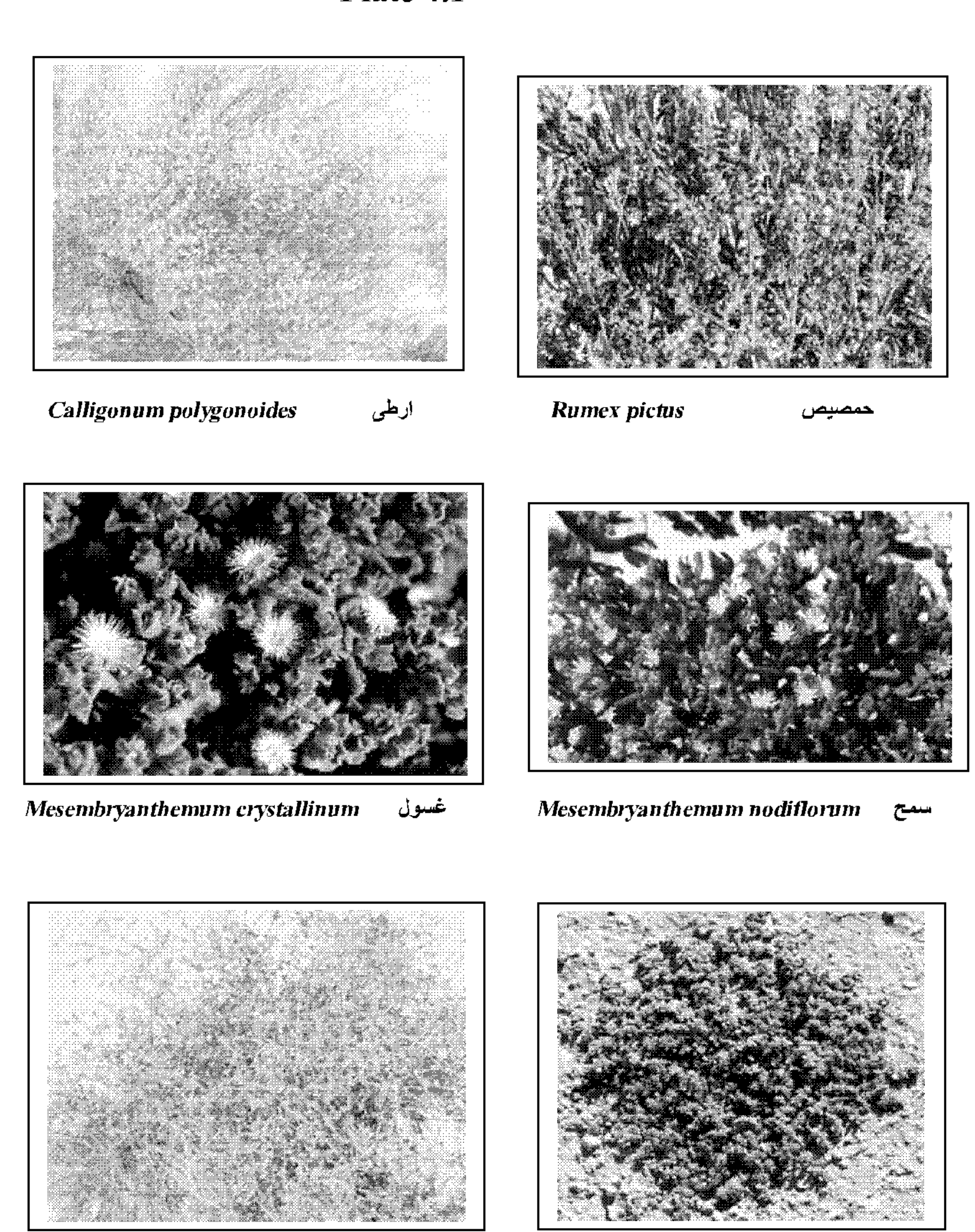
Plate 4.19
*Brachypodium distachyum***
Bromus lanceolata **
*Centropodia forsskaolii***
*Poa annua***

Plate 4.20
*Panicum turgidum**
Phragmites australis *
*Schismus arabicus**
*Stipa capensis**
*Stipagrostis scoparia***
*Stipagrostis plumosa***

Plate 4.21
*Cyperus laevigatus***
*Phoenix dactylifera**

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Plate 4.1



Calligonum polygonoides ارطى

Rumex pictus حمصيص

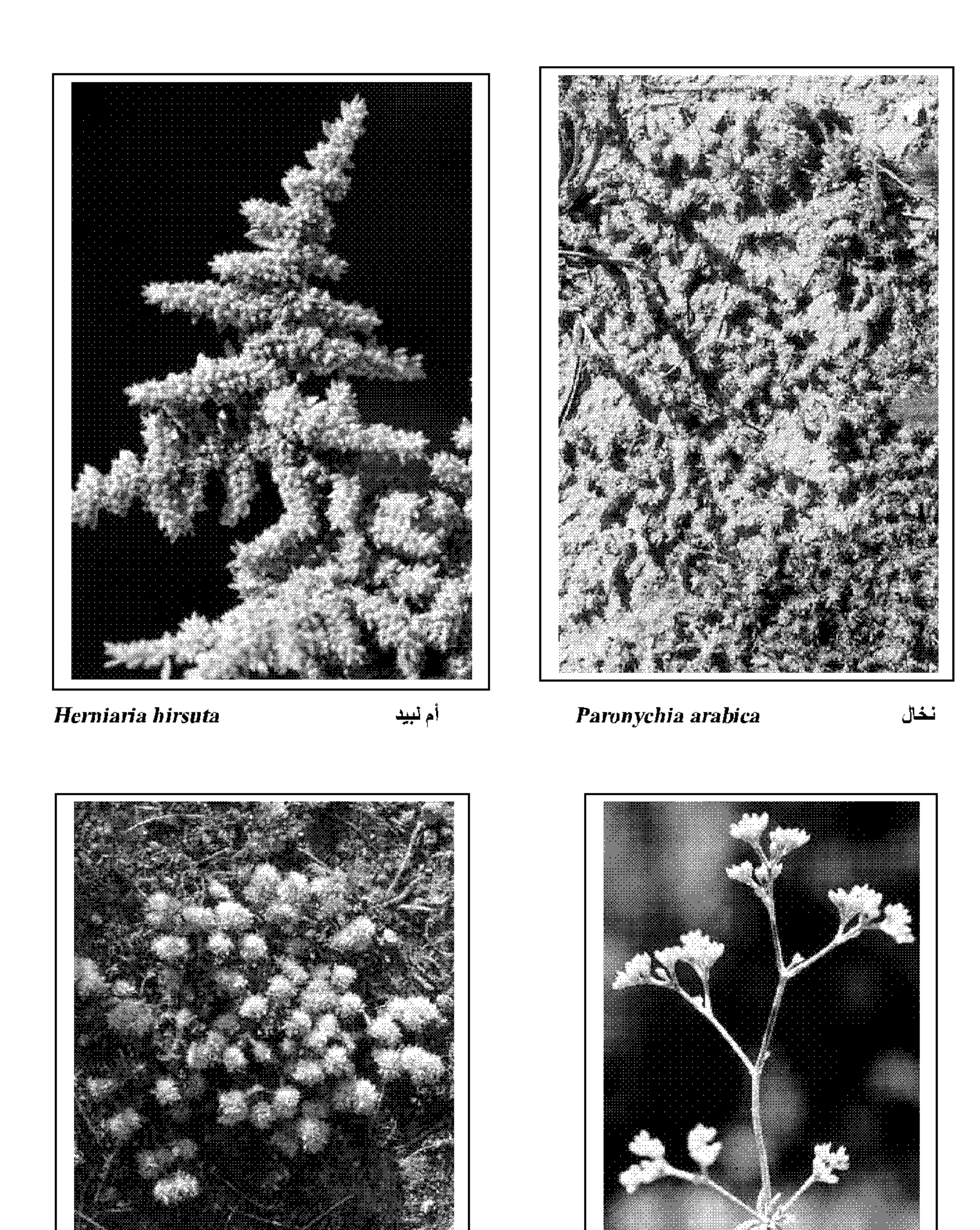
Mesembryanthemum crystallinum غسول

Mesembryanthemum nodiflorum سمح

Gymncarpos decandrus جرد

Herniaria hemistemon أم لبيد

Plate 4.2



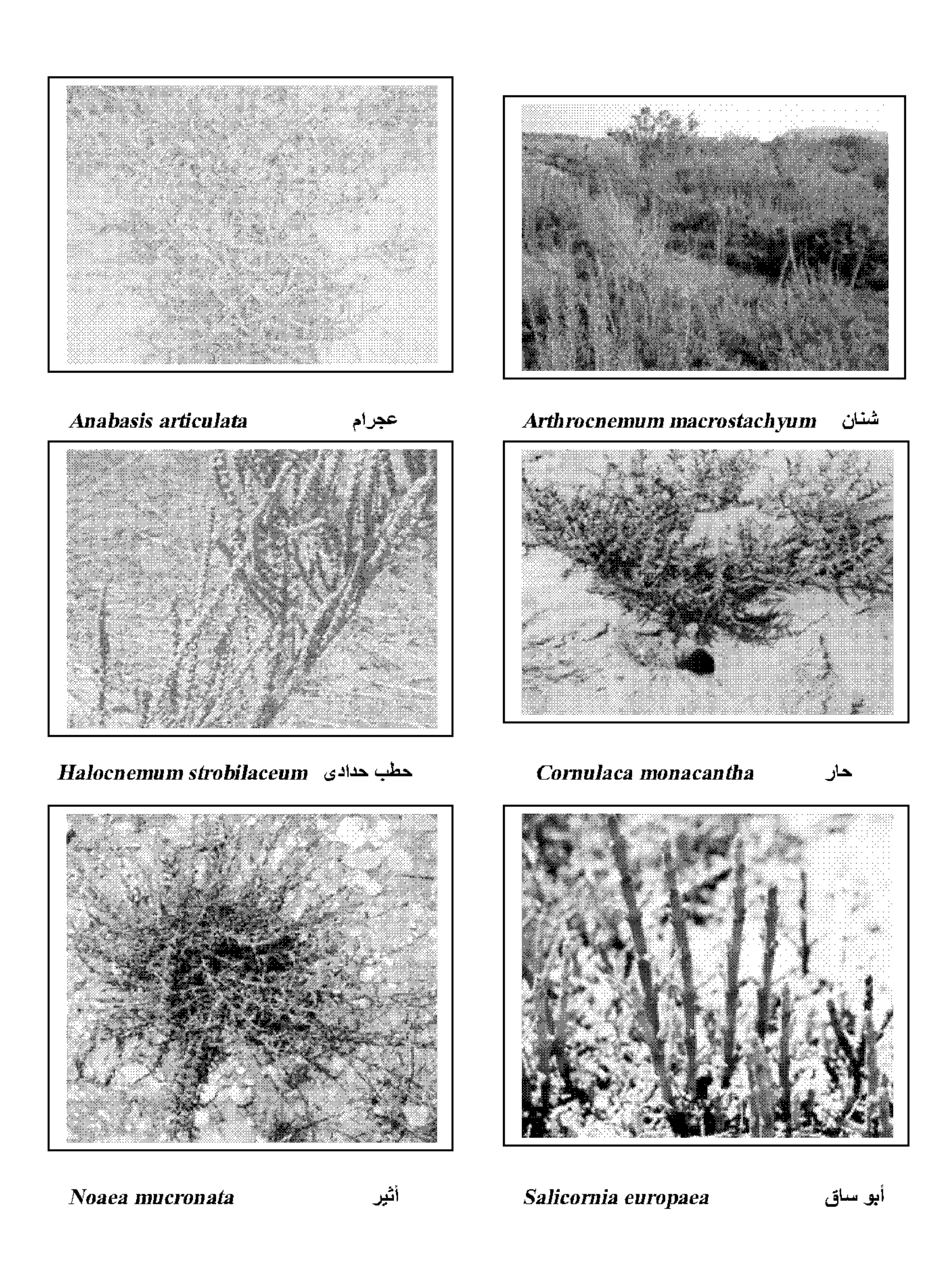
Herniaria hirsuta أم لبيد

Paronychia arabica نخال

Paronychia argentea بساط الأرض

Polycarpaea repens دقيقه

Plate 4.3



Anabasis articulata عجرام

Arthrocnemum macrostachyum شنان

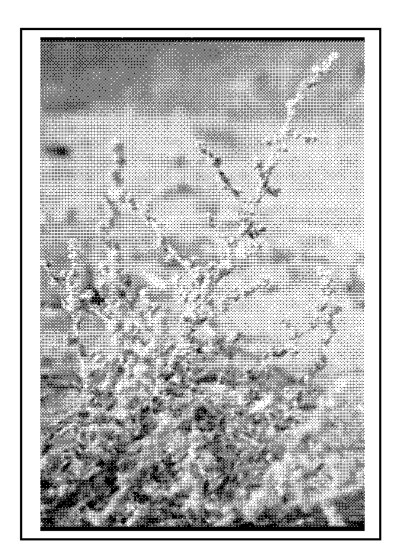
Halocnemum strobilaceum حطب حدادى

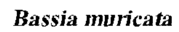
Cornulaca monacantha حار

Noaea mucronata أثير

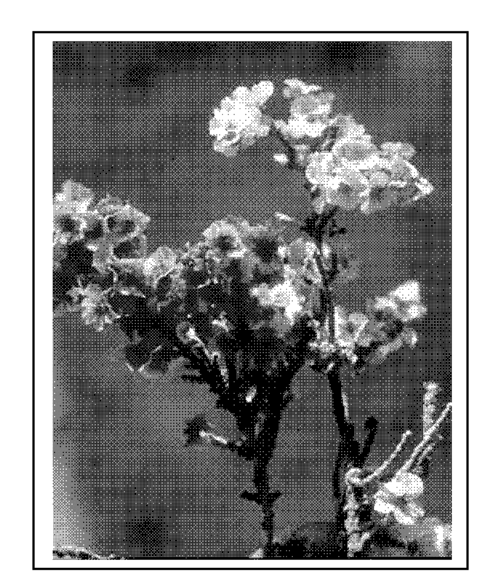
Salicornia europaea أبو ساق

Plate 4.4

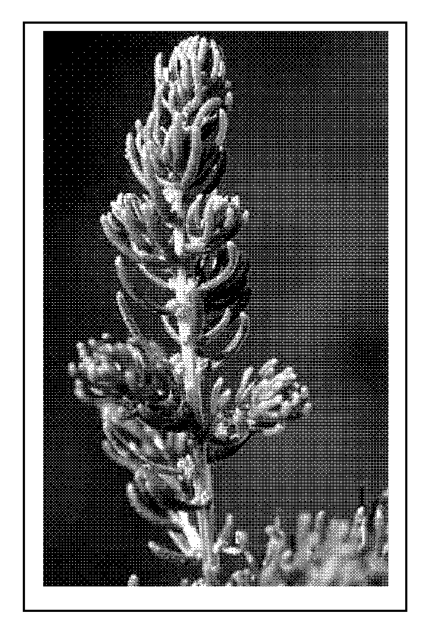




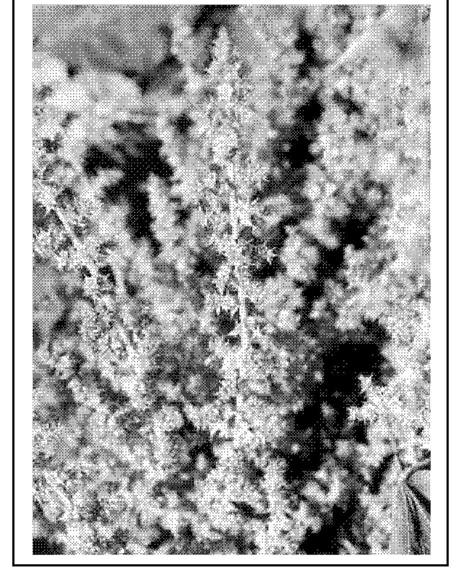
Bassia muricata هيثّام



Haloxylon scoparium طفوه

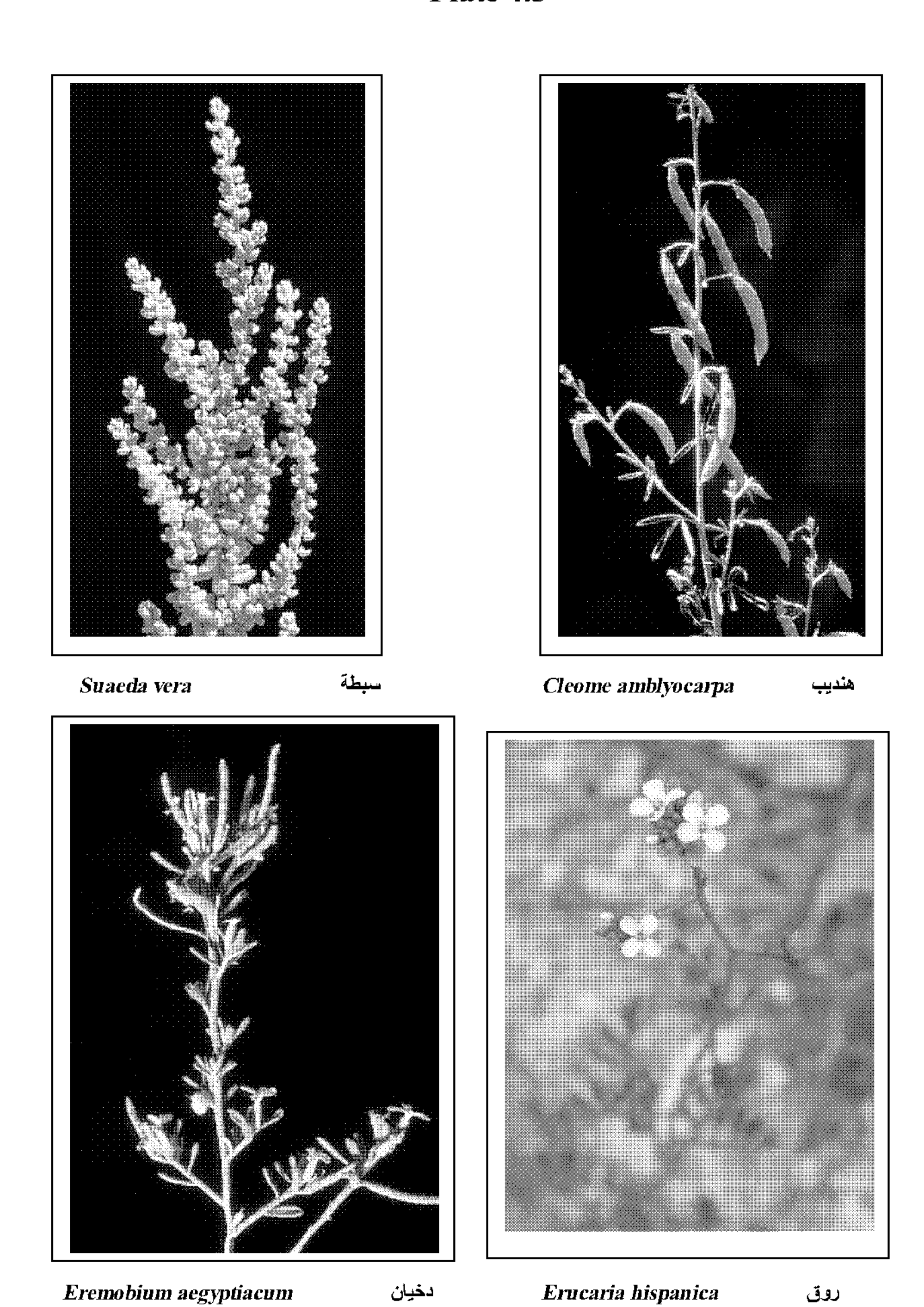


Suaeda aegyptiaca حطب سويدى



Salsola kali إشنان

Plate 4.5



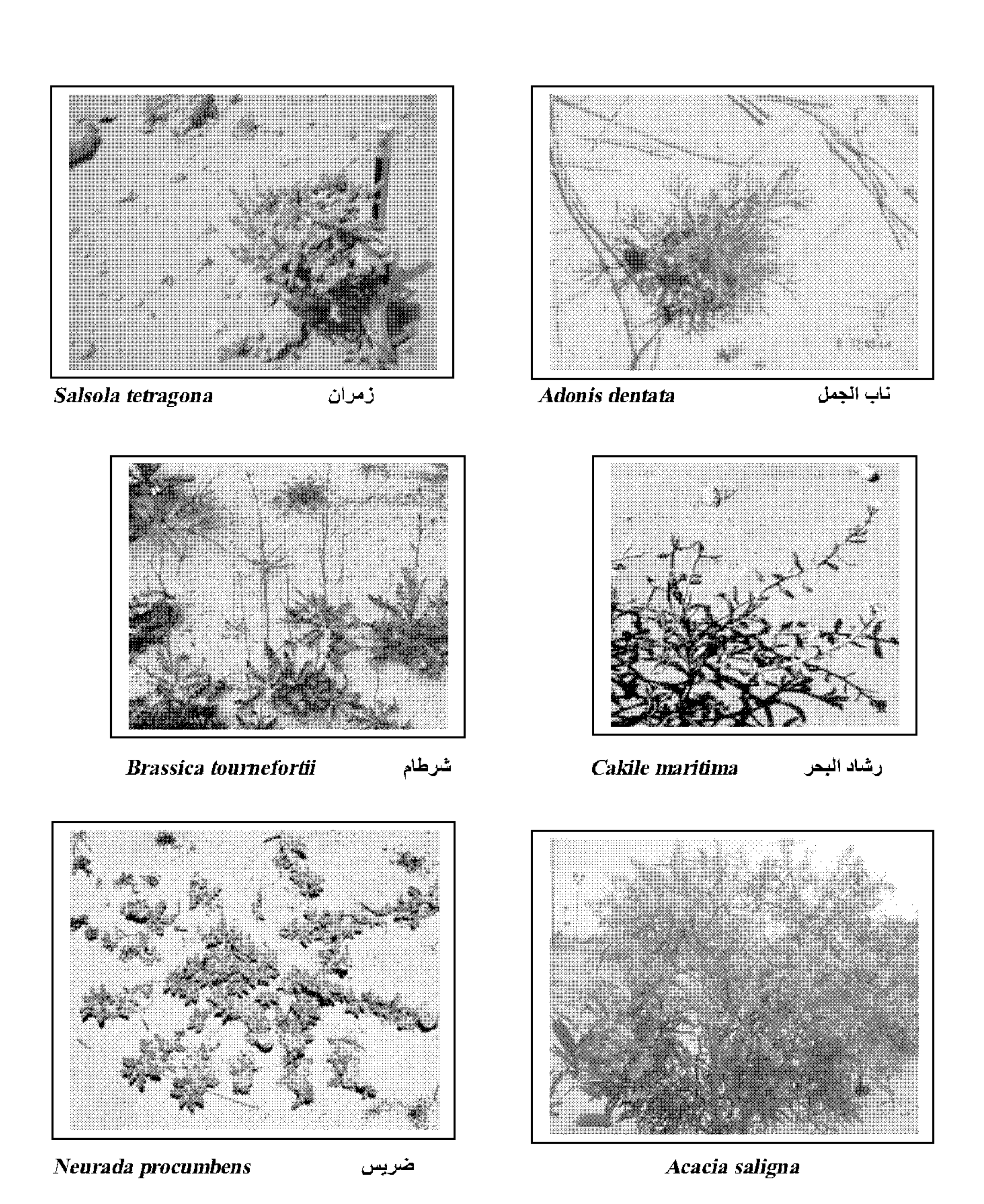
Suaeda vera سبطة

Cleome amblyocarpa هنديب

Eremobium aegyptiacum دخيان

Erucaria hispanica روق

Plate 4.6



Salsola tetragona زمران

Adonis dentata ناب الجمل

Brassica tournefortii شرطام

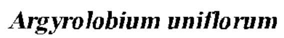
Cakile maritima رشاد البحر

Neurada procumbens ضريس

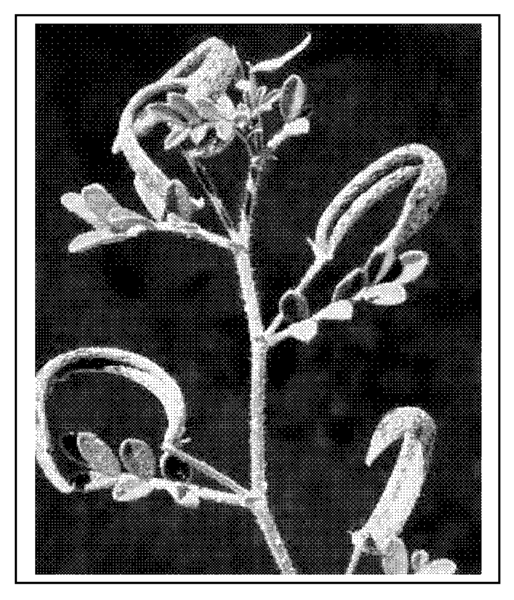
Acacia saligna

Plate 4.7

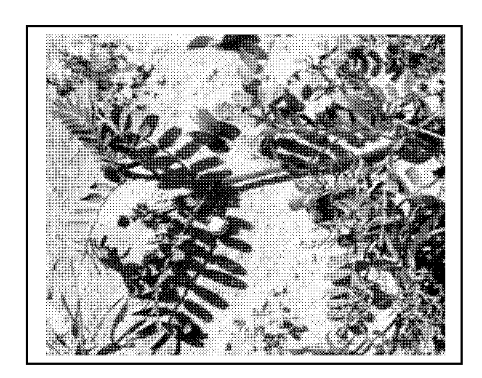




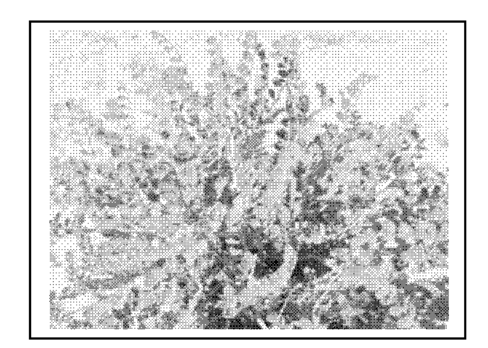
Argyrolobium uniflorum كود



Astragalus annularis كداد

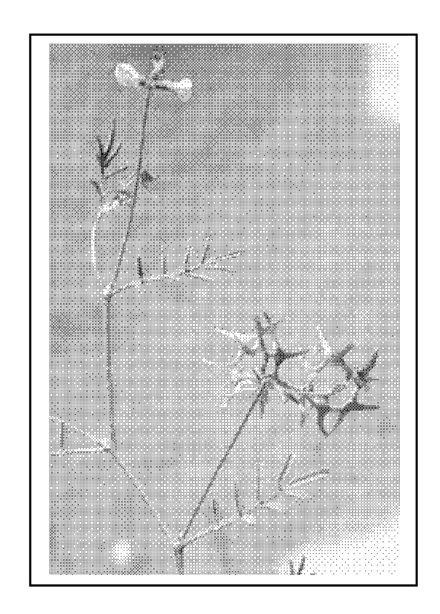


Astragalus boeticus محلاق



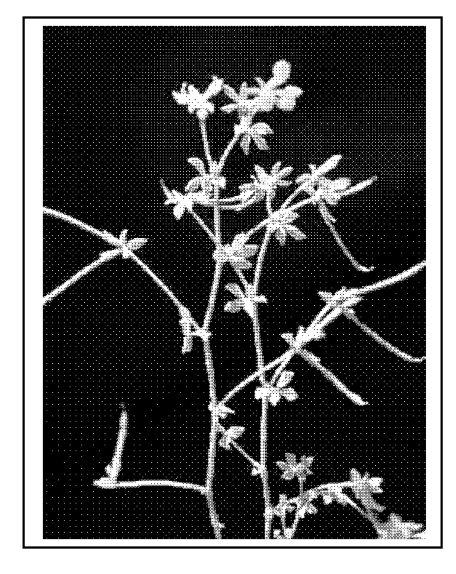
Astragalus kahiricus زب القط

Plate 4.8

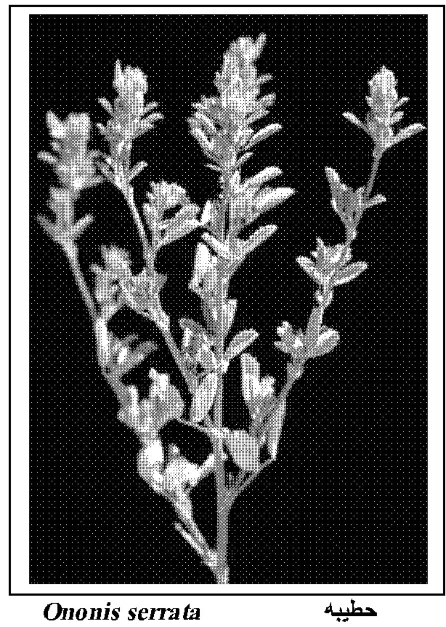




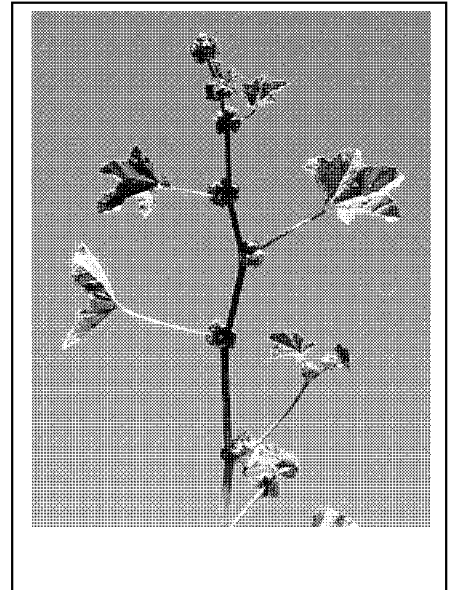
Hippocrepis areolata ضريس



Lotus halophilus حربيث

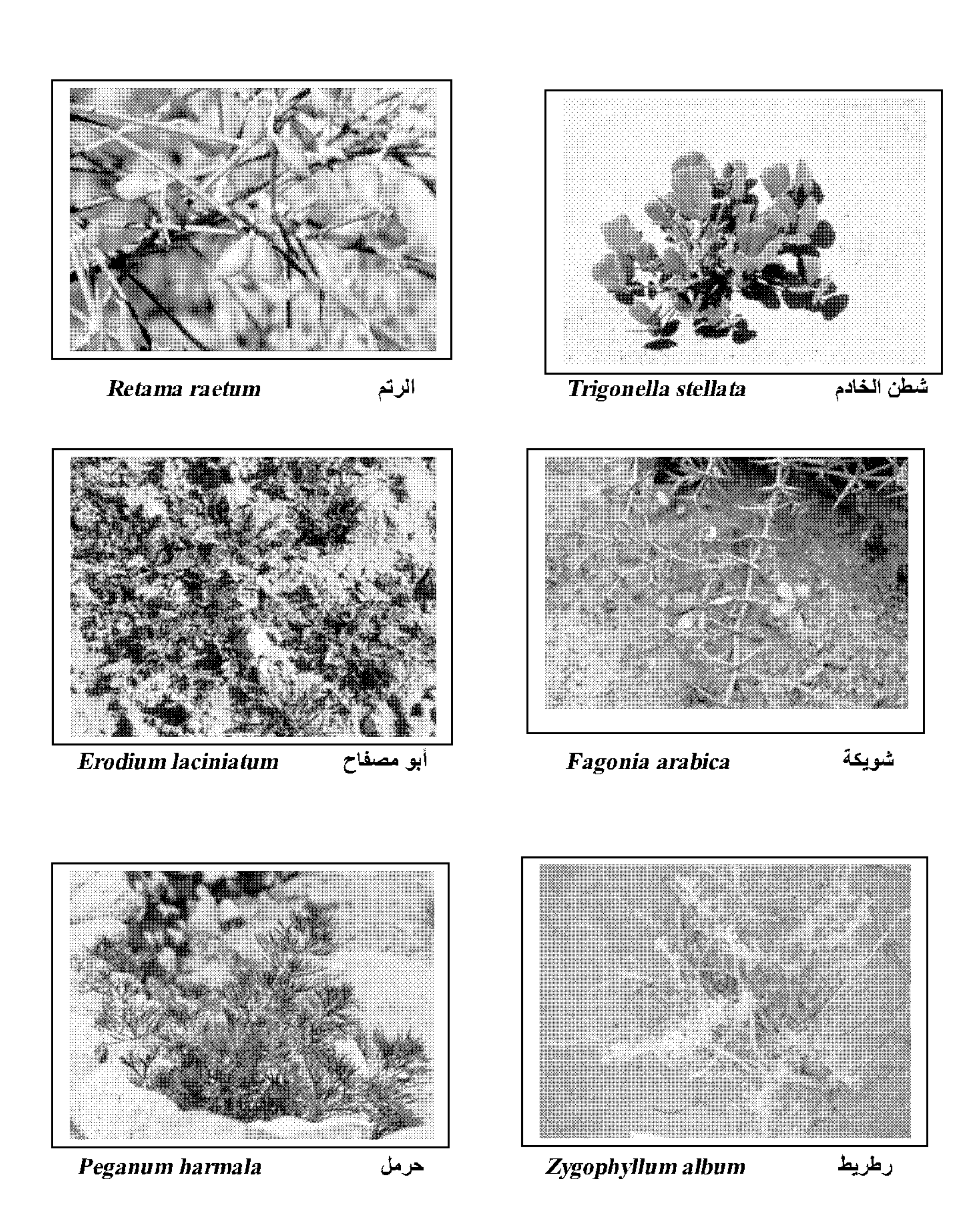


Ononis serrata حطيبه



Malva parviflora خبيزة

Plate 4.9



Retama raetum الرتم

Trigonella stellata شطن الخادم

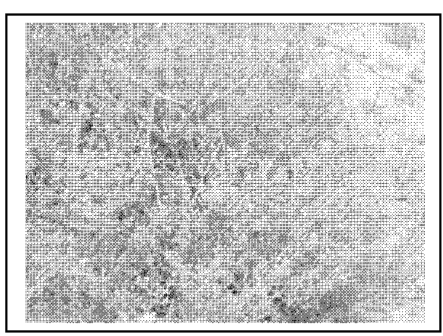
Erodium laciniatum أبو مصفاح

Fagonia arabica شويكة

Peganum harmala حرمل

Zygophyllum album رطريط

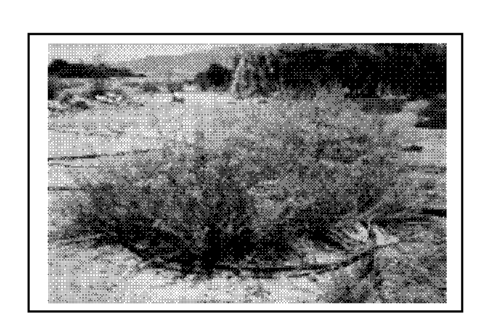
Plate 4.10



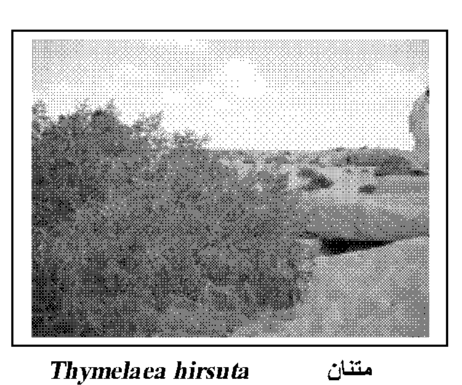
Zygophyllum coccineum **رطريط اخضر**



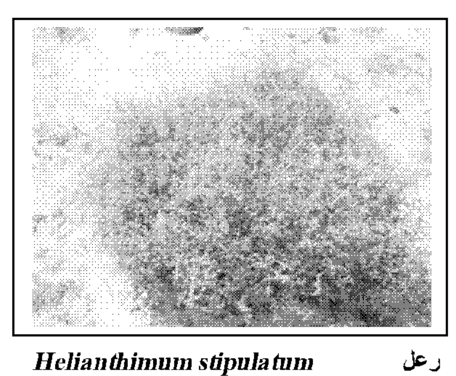
Nitraria retusa **غرقد**



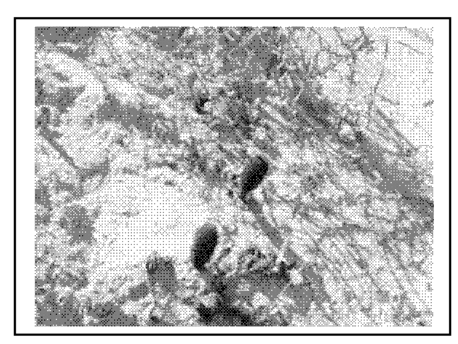
Haplophyllum tuberculatum **شجرة الكلب**



Thymelaea hirsuta **متنان**

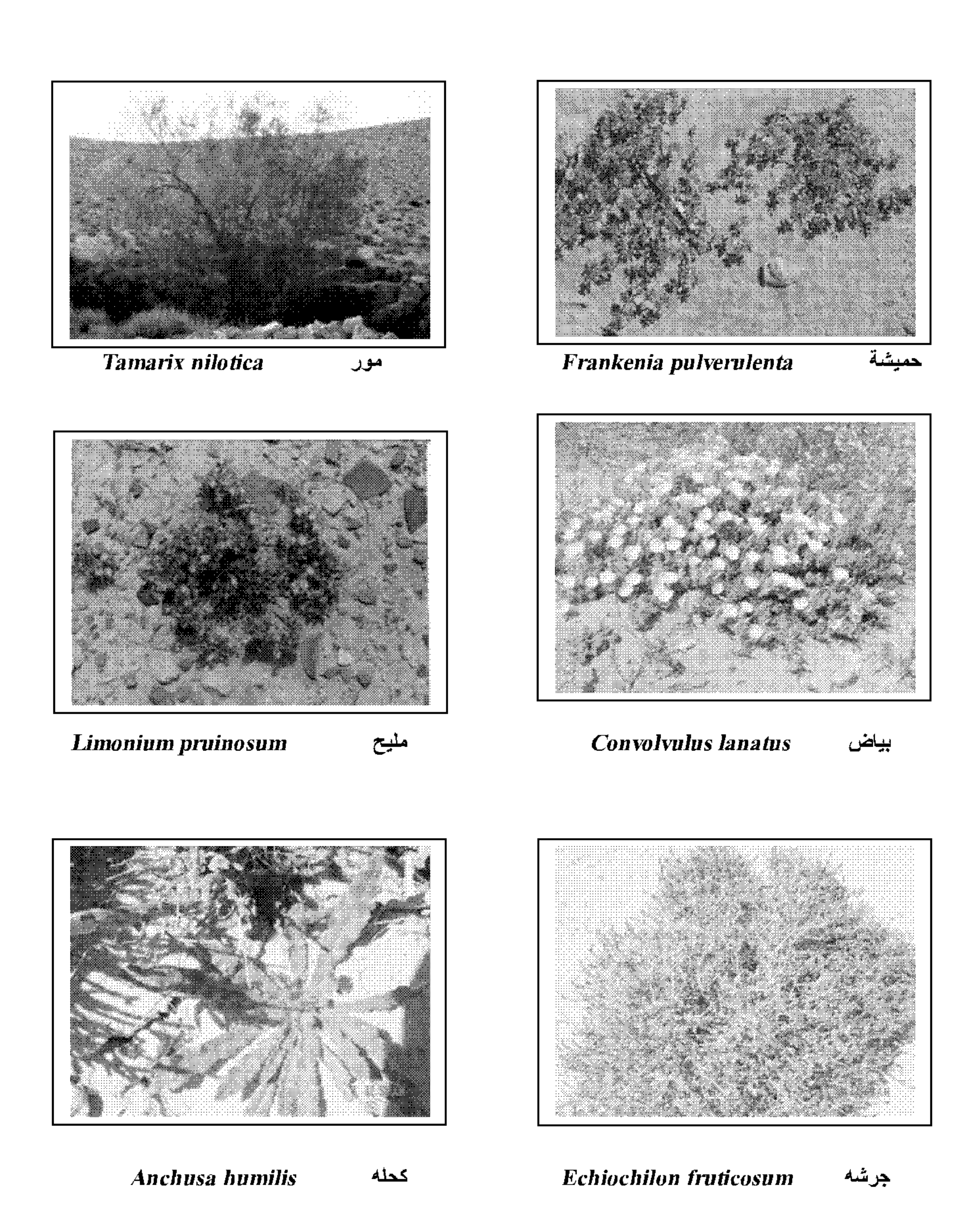


Helianthimum stipulatum **رعل**



Cynomorium coccineum **زب الأرض**

Plate 4.11



Tamarix nilotica مور

Frankenia pulverulenta حميشة

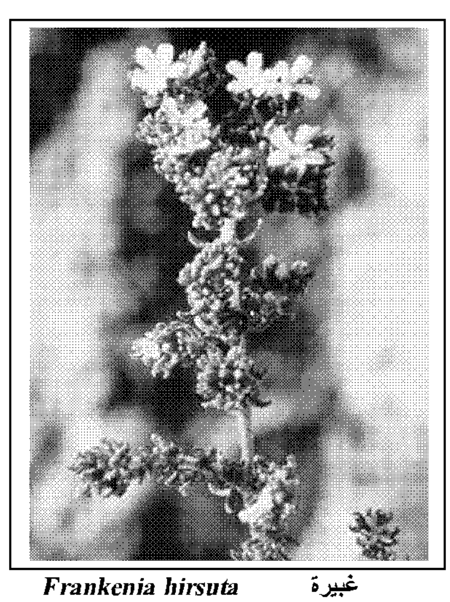
Limonium pruinosum مليح

Convolvulus lanatus بياض

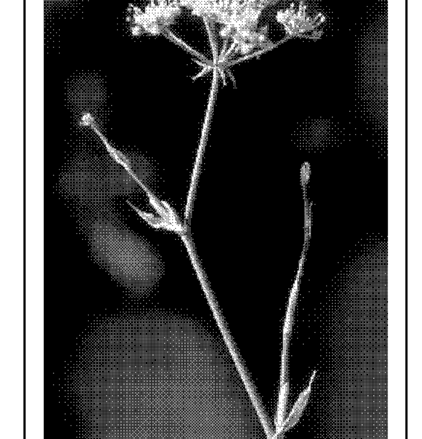
Anchusa humilis كحله

Echiochilon fruticosum جرشه

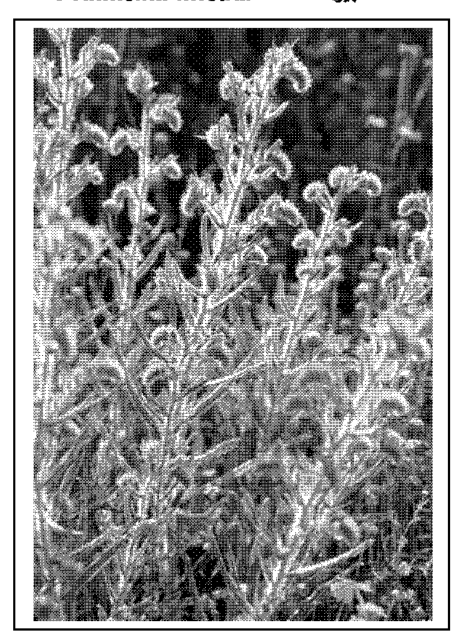
Plate 4.12



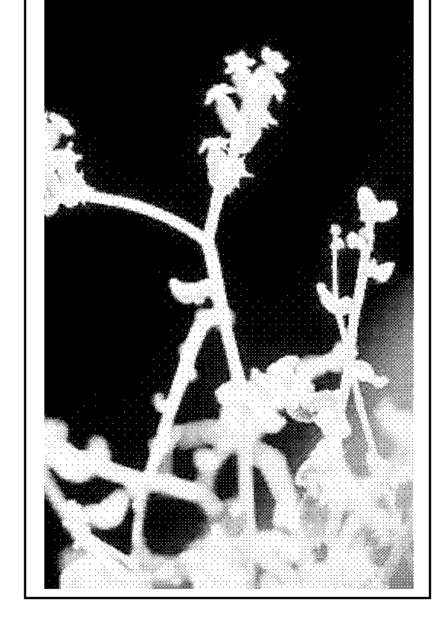

Frankenia hirsuta **غبيرة**



Deverra tortuosa **قزوح**

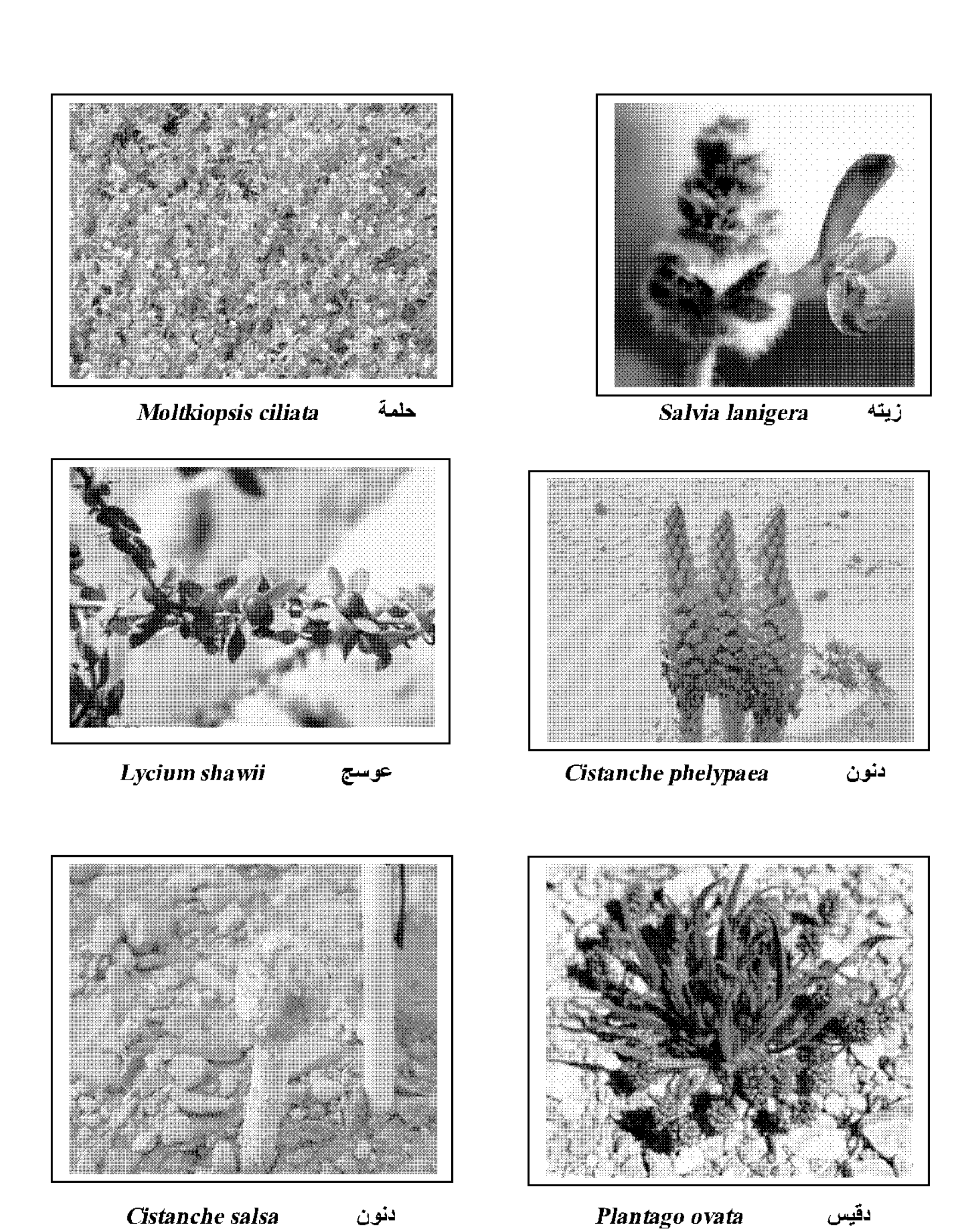


Echium angustifolium **حنا الغول**



Heliotropium digynum **حلانيه**

Plate 4.13



Moltkiopsis ciliata حلمة

Salvia lanigera زيته

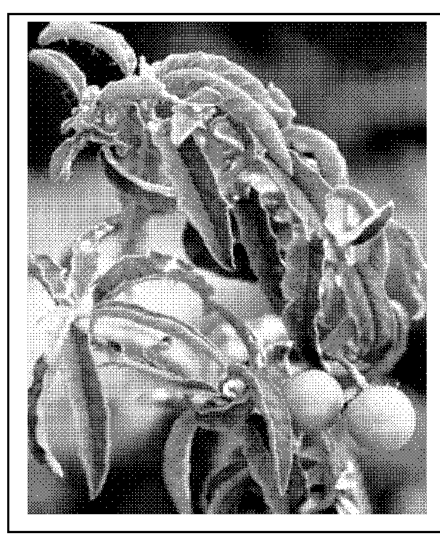
Lycium shawii عوسج

Cistanche phelypaea دنون

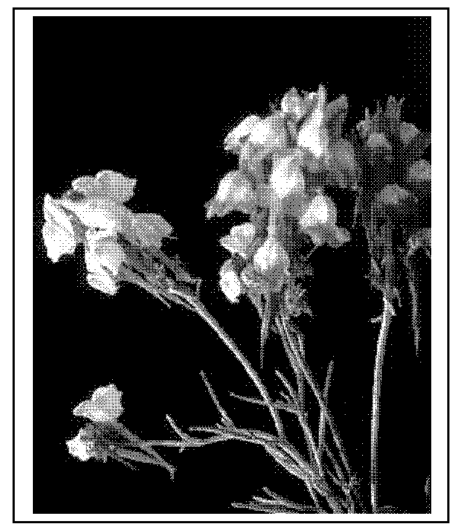
Cistanche salsa دنون

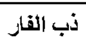
Plantago ovata دقيس

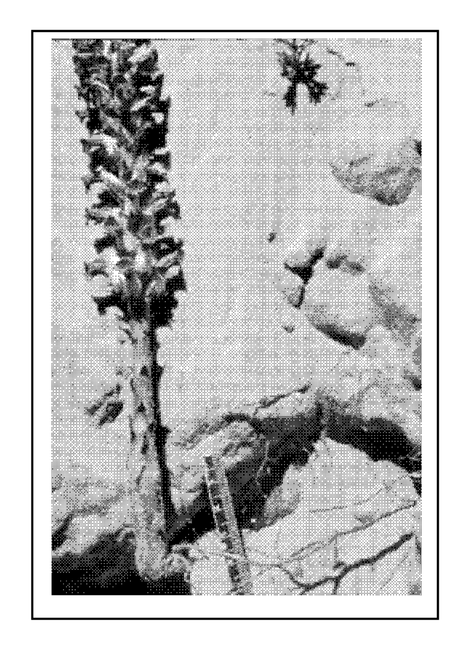
Plate 4.14



Solanum elaeagnifolium



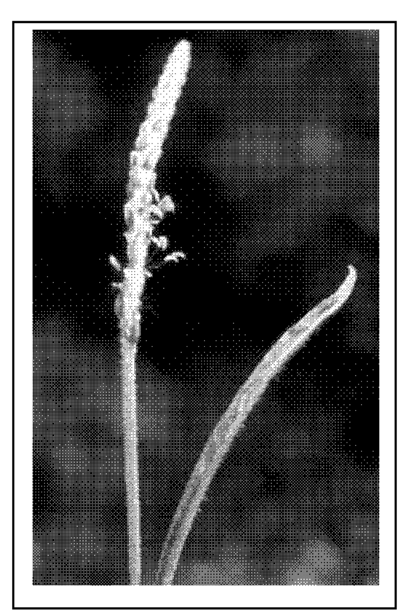
Linaria haelava 



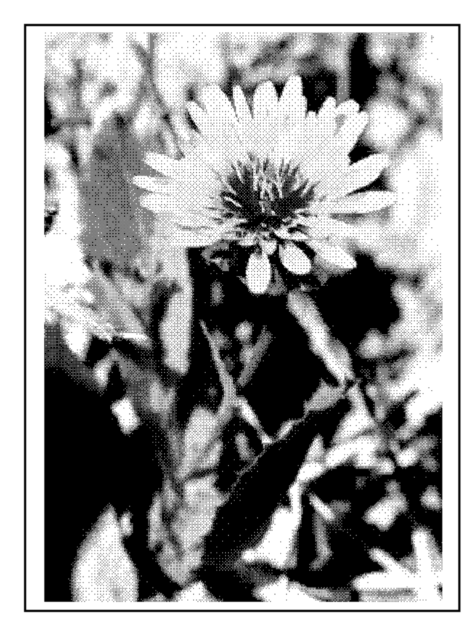
Orobanche cernnua 

Plantago albicans لقمة النعجة

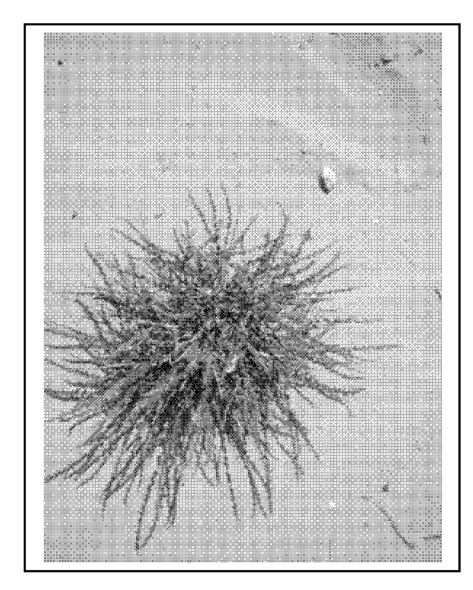
Plate 4.15



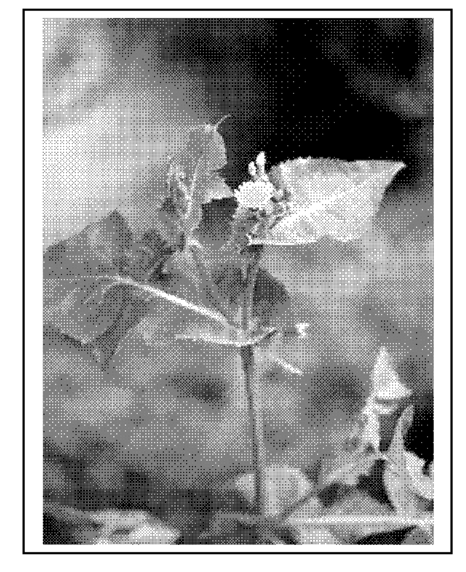
Plantago cylindrica برخمى



Reichardia tingitana عضيد

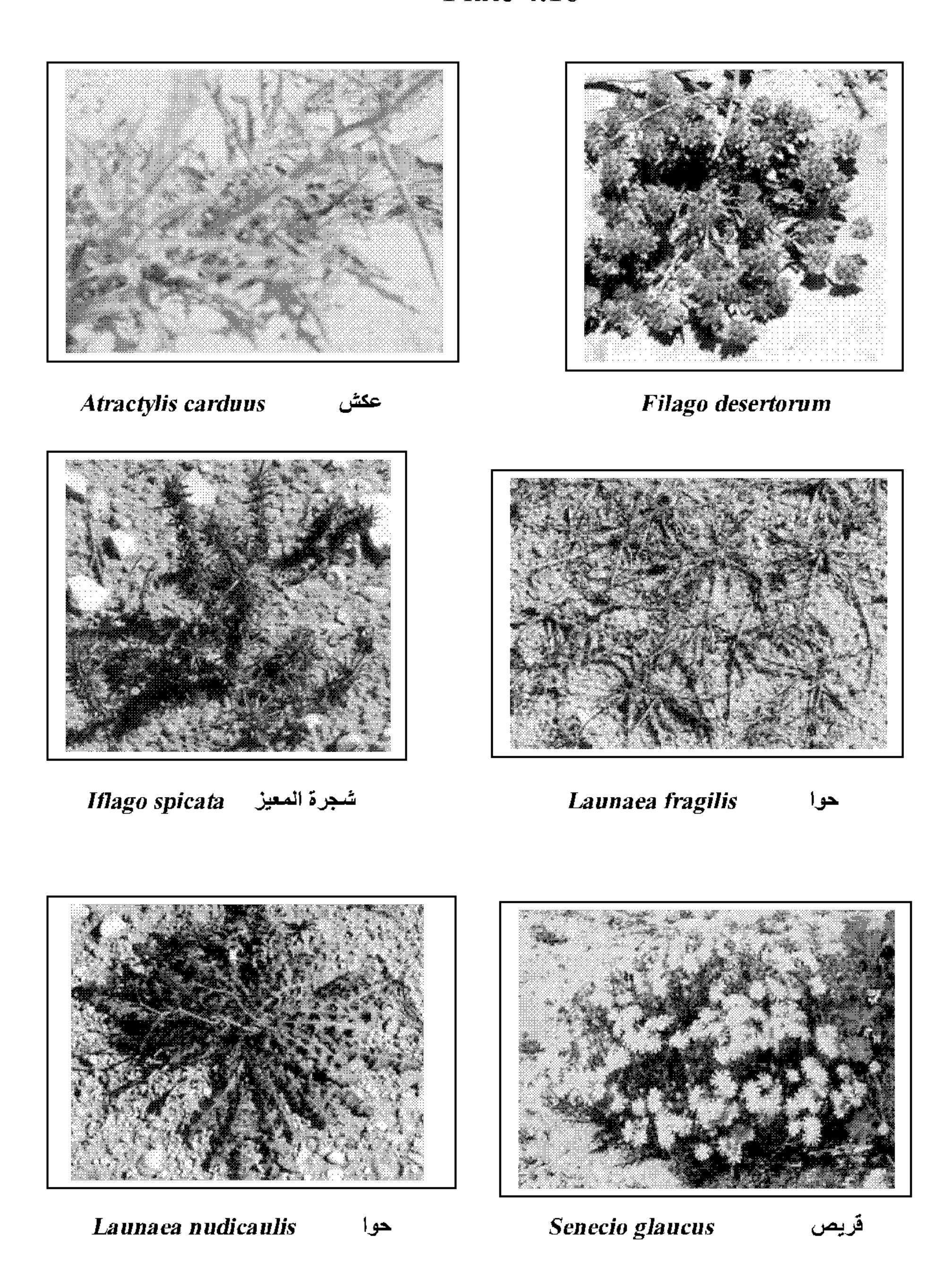


Artemisia monosperma بعيثران



Soncuhs oleraceous جعضيض

Plate 4.16



Atractylis carduus عكش

Filago desertorum

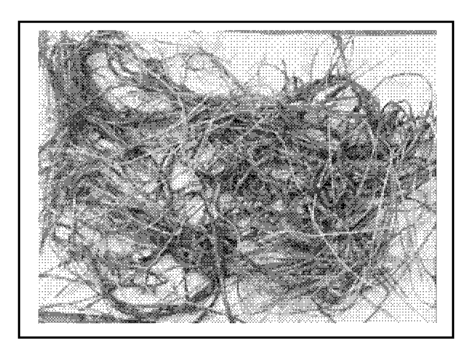
Iflago spicata شجرة المعيز

Launaea fragilis حوا

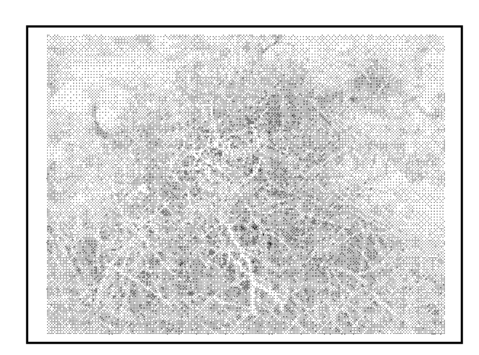
Launaea nudicaulis حوا

Senecio glaucus قريص

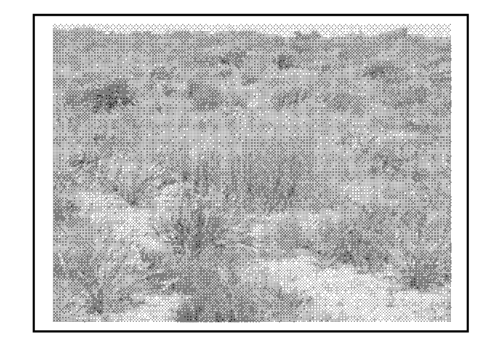
Plate 4.17



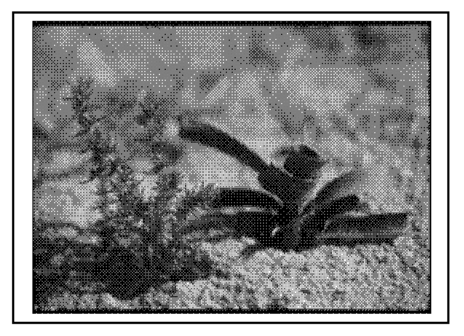
Ruppia cirrhosa ريم



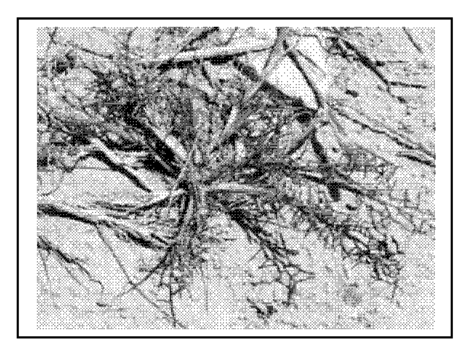
Asparagus stipularis عقول برى



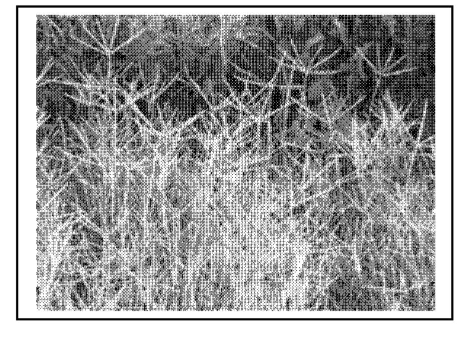
Pancratium maritimum زمبق



Pancratium sickenbergeri عيصلان

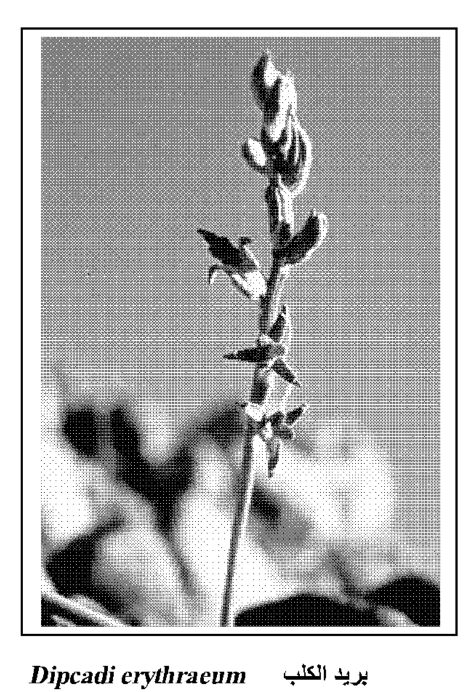


Cutandia memphitica صامه



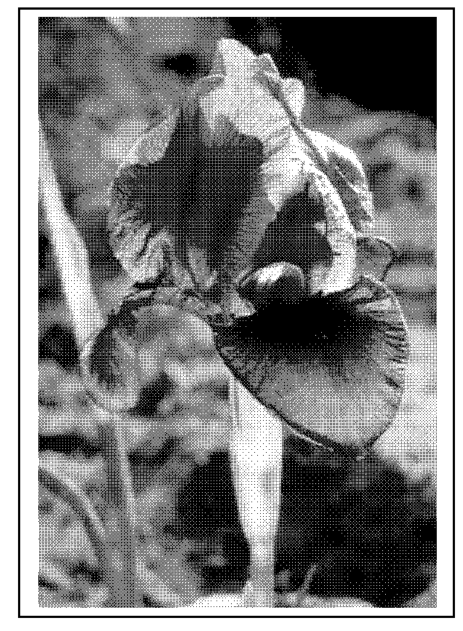
Cynodon dactylon نجيل

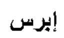
Plate 4.18



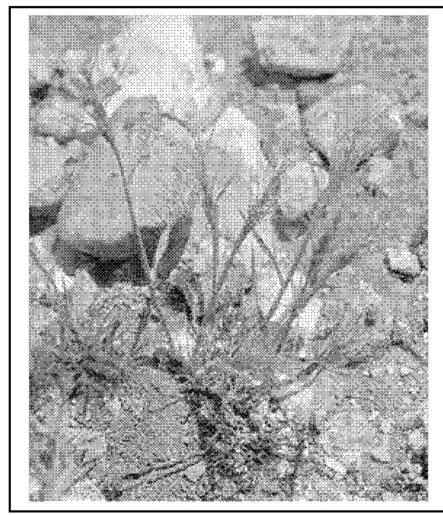


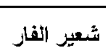
Dipcadi erythraeum بريد الكلب



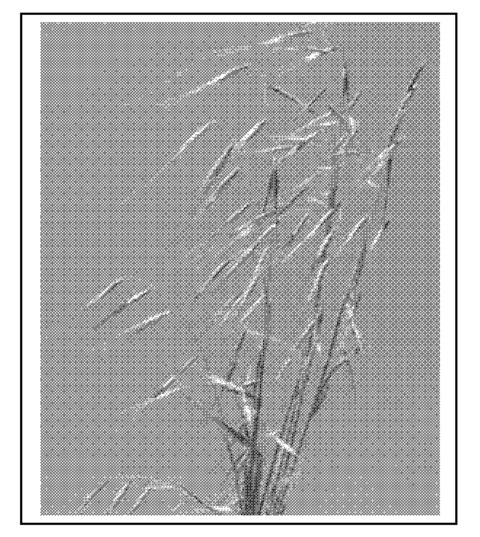


Iris mariae إبرس



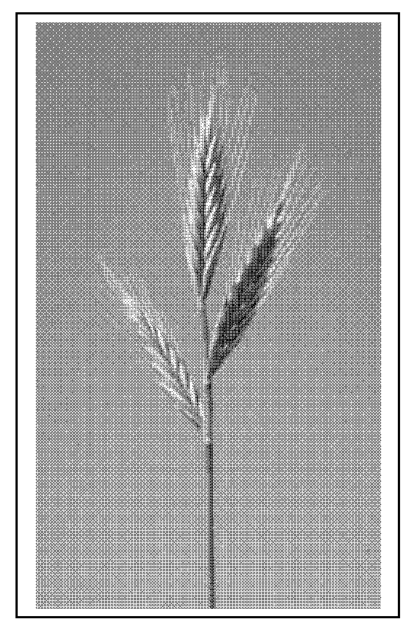


Aegilops kotschyi شعير الفار

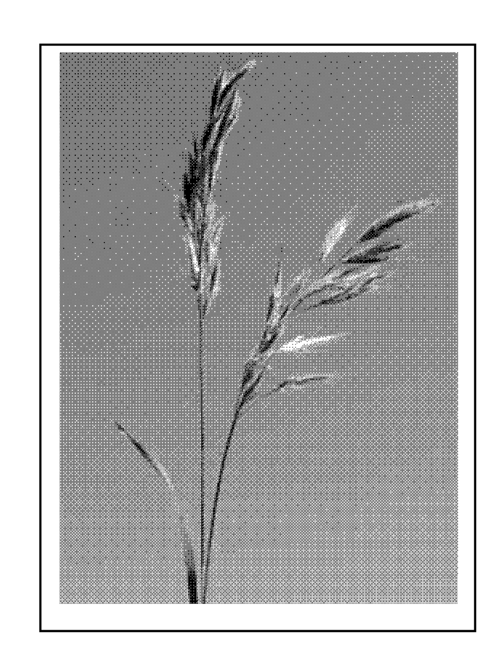


Avena barbata بهمى

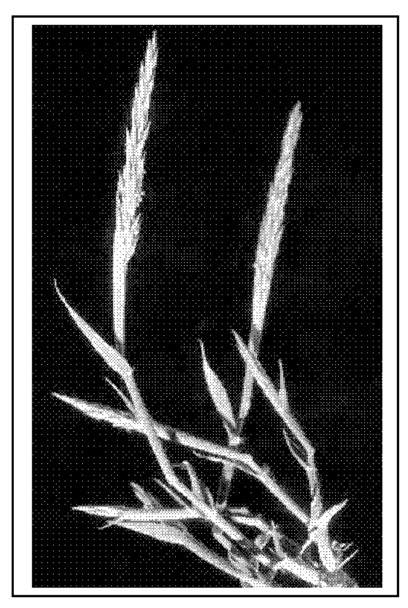
Plate 4.19



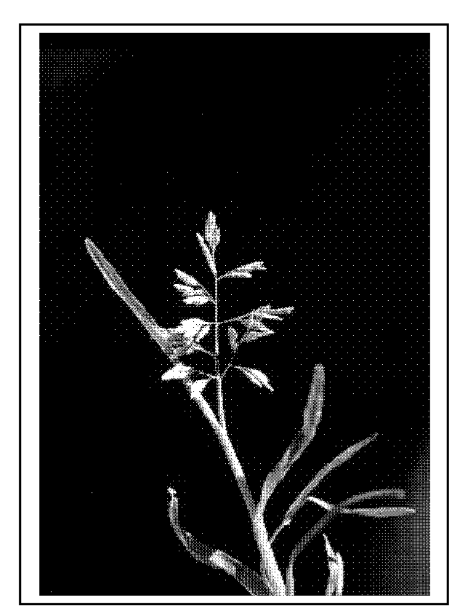
Brachypodium distachyum **ياداب**



Bromus lanceolata **خفور**

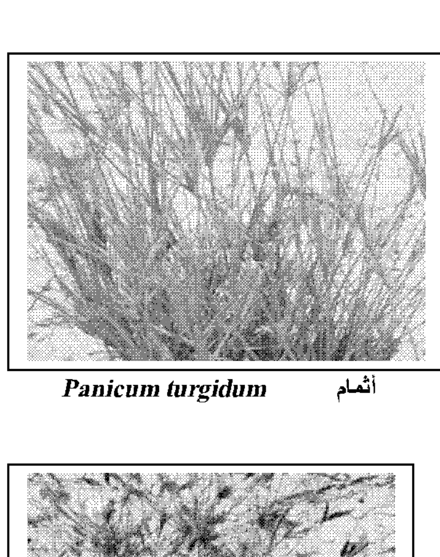


Centropodia forsskaolii **عكريش**

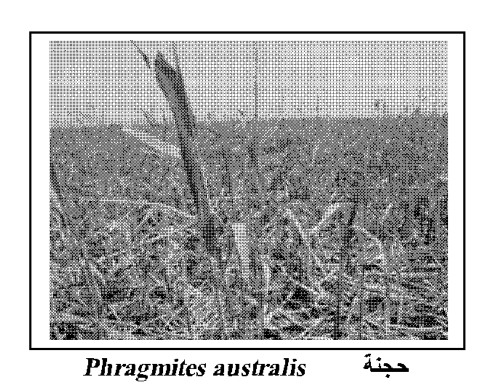


Poa annua **سبل أبو الحسين**

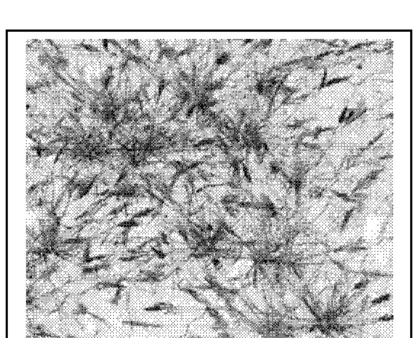
Plate 4.20



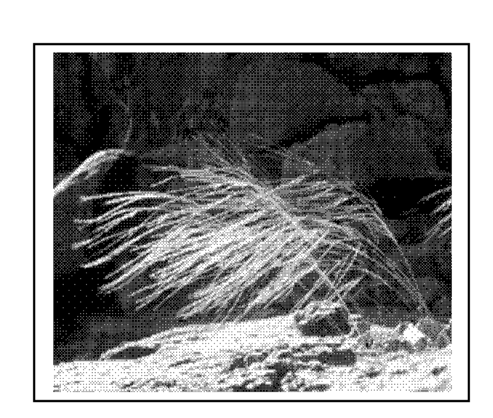
Panicum turgidum أثمام



Phragmites australis حجنة



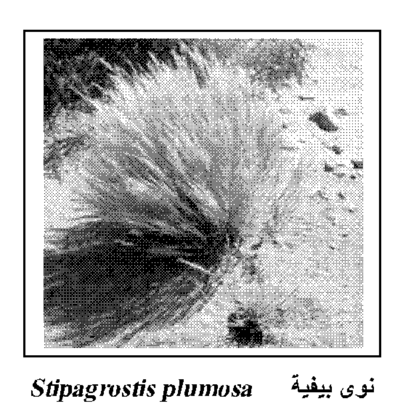
Schismus arabicus بهمى



Stipa capensis أبو فاخور

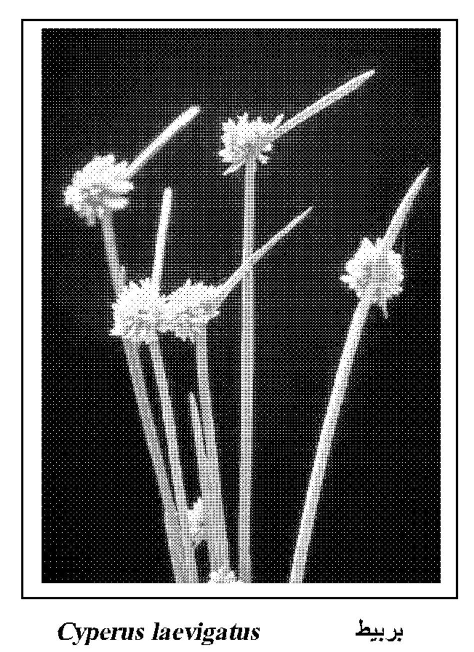


Stipagrostis scoparia نصى



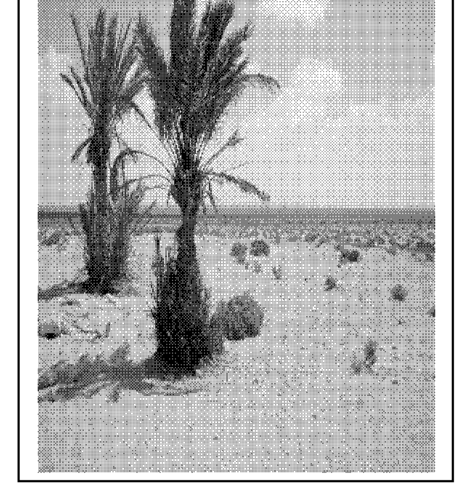
Stipagrostis plumosa نوى بيفية

Plate 4.21





Cyperus laevigatus بربيط



Phoenix dactylifera نخيل البلح

Chapter 5
Phytoplankton and Periphytic Algae

Fish production in Egypt depends largely on the Egyptian shallow water bodies such as Lake Bardawil. The role of phytoplankton as a main source of fish nutrition is well known, and in order to develop the fish economy it is necessary to study the phytoplankton and the factors affecting its standing crop and productivity. Bardawil Lagoon is a unique water body, hyper-saline, shallow and situated in an arid area in north Sinai. Although its water and organisms originated from the Mediterranean, its phytoplankton, and periphytic algae are qualitatively and quantitatively differ from all most adjacent water bodies. The data available about the *autotrophs* of Bardawil Lagoon are scarce compared with that of other Egyptian Mediterranean lagoons.

5.1 PHYTOPLANKTON

5.1.1 Species Diversity

The diversity of phytoplankton in Bardawil Lagoon, as other oligotrophic lakes, is characterized by high species diversity if compared with the eutrophic water bodies. During the period from 1985 to 2002, the data available revealed that 241 species were recorded (Table 5. 1) in Bardawil Lagoon; diatoms were represented by 159 species, followed by dinoflagellates with 53 species. Cyanophytes, chlorophytes and chrysophytes were lesser recorded, and represented by 15, 8 and 4 species, respectively. Recently during 2000 (Touliabah *et al.* 2002) the two groups; Cryptophyceae and Euglenophyceae were recorded and each represented by one species. As shown in Table (5.1), among the 241 recorded species, only 12 were common and documented in all investigations, while 56 ones are considered as new species that invaded the lagoon. The species belonging to Euglenophyceae and Chrysophyceae were sporadic, while the cryptomonodales (*Rhodomonas minuta* var. *nanoplanktonica*) were perennial species (Shabana 1999,Touliabah *et al.* 2002). It is noted that the species diversity

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of phytoplankton is high near the inlets compared with the center of the lagoon; this decrease is obviously related to the increase in salinity (Taha 1990). Her findings agree with Ehrlich (1975), who documented a decrease in number of phytoplankton species southward in the lagoon, due to increase in salinity.

Table 5.1. **Inventory of phytoplankton species recorded in Bardawil Lagoon from 1985 to 2002**

Species	Fouda *et al.* (1985)	Taha (1990)	Shabana (1999)	Touliabah *et al.* (2002)
Bacillariophyceae				
Achnanthes brevipes Ag.	-	+	+	+
Achnanthes exigua Grun	-	-	+	+
Actinoptychus undulates Ehren	+	-	-	-
Amphiprora alata (Kutz.)	-	+	+	+
Amphiprora marina Greg	+	-	-	-
Amphiprora gigantea Grun	+	-	-	-
Amphiprora paludosa W. Sm.	-	-	+	+
Amphiprora surirelloides Hendey	-	+	-	-
Amphora coffaeiformis Ag	-	+	+	+
Amphora ostrearia Breb.	-	-	+	+
Amphora ovalis (Kutz.)	+	-	+	+
Amphora holsatica Hust	-	+	-	-
Amphora granulata Greg.	-	+	-	-
Amphora kolbei Aleem	-	+	-	-
Asterionella japonica Cl.	+	+	+	+
Asterionella notata Hust	+	-	-	-
Bacillaria paradoxa (Gmel.) Grun	+	+	+	+
Bacteriastrum delicatulum Cleve.	-	+	-	-
Bacteriastrum hyalinum Laud.	-	+	+	+
Biddulphia mobiliensis Bailey	-	+	+	+
Biddulphia obtuse (Kz.) Ralf.	+	-	-	-
Campylodiscus hibernicus Ehren.	-	-	+	+
Campylostylus striatus Shadbolt	-	+	+	+
Cerataulina pelagica Grun	+	-	-	-
Chaetoceros brevis (Schutt)	-	+	+	+
Chaetoceros curvisetus Clev.	-	+	+	+
Chaetoceros didymus (Ehren.)	-	-	+	+
Chaetoceros affinis Laud	-	+	-	-
Chaetoceros compressa Laud.	-	+	-	-
Climacosphenia moniligera Ehren	+	-	-	-
Climacosphenia elongata Cl.	+	-	-	-
Cocconeis bardawillensis Ehren.	-	+	+	+
Cocconeis placentula Ehren.	-	+	+	+
Cocconeis scutellum Ehren	-	+	+	+
Cocconeis scutellum var. *parvum* Grun.	-	+	-	-
Cocconeis sp.	+	-	-	-
Coscinodiscus lineatus (Ehren.)	+	+	+	+
Coscinodiscus centralis Ehren.	+	-	-	-
Coscinodiscus excentricus Ehren.	+	+	-	-
Coscinodiscus granii (Ostf) Hust.	+	-	-	-
Coscinodiscus radiatus Hust.	+	+	-	-
Coscinodiscus perforatus Ehren.	+	-	-	-

Species	Fouda *et al.* (1985)	Taha (1990)	Shabana (1999)	Touliabah *et al.* (2002)
Coscinodiscus alborani *Moll.*	+	-	-	-
Coscinodiscus nitidus **Greg.**	-	+	-	-
Cyclotella comta **(Ehren.) Kutz.**	-	-	+	+
Cyclotella kutzingiana **Chauv.**	-	+	-	-
Cyclotella meneghiniana **Kutz.**	+	-	+	+
Cyclotella ocellata **Pant.**	-	+	+	+
Cymbella parva **(W. Sm.) Cleve**	-	-	+	+
Cymbella ventricosa **var.** ***ovata*** **(Agard.) Kutz.**	-	-	+	+
Cymbella **sp.**	+	-	-	-
Dimeregramma marina **(Greg.) Ralf.**	-	+	-	-
Diploneis elliptica **(Kutz.) Cleve**	-	-	+	+
Diploneis ovalis **(Hilse.) Cleve**	-	-	+	+
Epithemia sorex **(Kutz.)**	-	-	+	+
Eucampia zodiacus **Ehren.**	+	-	-	-
Fragilaria construens **(Ehr.) Grun.**	-	-	+	+
Gomphonema parvulum **(Kutz.) Grun.**	-	-	+	+
Grammatophora marina **(Lyng) Kz**	+	-	-	-
Grammatophora oceanica **(Ehren.) Grun.**	-	+	-	-
Gunardia flaccida **(Cast.) Pereg.**	-	+	-	-
Gyrosigma acuminatum **(Kutz.) Rabh.**	-	-	+	+
Gyrosigma acuminatum **var.** ***balticum*** **(Ehren.) Rabh.**	-	+	-	-
Gyrosigma balticum **(Ehren) Rabh.**	-	-	+	+
Gyrosigma spencerii **(Smith) Cl.**	+	-	-	-
Gyrosigma scalproides **(Rabh.) Cleve**	-	+	-	-
Gyrosigma ***eximium*** **(Thw.)**	-	+	-	-
Hantzschia amphioxys **(Ehren.) Grun.**	-	+	-	-
Hemialus hauckii **(Grun.)**	-	+	+	+
Hemialus sinensis **Grev.**	-	+	-	-
Hemidiscus cuneiformis **Wallich**	+	-	-	-
Leptocylindrus danicus **(Celve.)**	+	+	+	+
Licmophora flabellata **(Grun.) Ag.**	-	+	+	+
Licmophora abbreviata **Agard.**	-	+	-	-
Licmophora ehrenbergii **(Kutz.) Grun.**	-	+	-	-
Licmophora gracilis **(Ehren.) Grun.**	-	+	-	-
Licmophora lyngbyei **(Kz) Grun**	+	-	-	-
Lithodesmium undulatum **Ehren.**	-	+	-	-
Mastogloia braunii **Grun.**	+	+	+	+
Mastogloia pumila **(Grun.) Cl.**	+	-	-	-
Mastogloia smithii **var.** ***amphicephala*** **Grun.**	-	-	+	+
Mastogloia smithii **var.** ***heteroloculata*** **nov.**	-	+	-	-
Mastogloia apiculata **Smith**	-	+	-	-
Mastogloia angulata **Lewis**	-	+	-	-
Melosira granulata **(Ehr.) Ralf.**	-	+	+	+
Melosira sulcata **(Ehren.) Kz.**	+	-	-	-
Melosira moniliformis **Hust.**	+	+	-	-
Navicula abrupta **Greg.**	-	-	+	+
Navicula cryptocephala **(Kutz.)**	-	-	+	+
Navicula distans **Smith**	+	-	-	-
Navicula membranacea **Cl.**	+	-	-	-
Navicula salinarum **Grun.**	-	-	+	+
Navicula trevelyana	+	-	-	-
Navicula cancellata **Donkin.**	-	+	-	-
Navicula mutica **Kutz.**	-	+	-	-
Navicula scopulorum **Breb.**	-	+	-	-

Species	Fouda *et al.* (1985)	Taha (1990)	Shabana (1999)	Touliabah *et al.* (2002)
Navicula tuscula Ehren.	-	+	-	-
Navicula directa Smith	-	+	-	-
Navicula lyra Ehren.	-	+	-	-
Nitzschia acicularis Smith	-	-	+	+
Nitzschia amphibia Grun.	-	-	+	+
Nitzschia bilobata Smith	+	-	-	-
Nitzschia closterium Smith	-	+	+	+
Nitzschia frustulum var. *subsalina* Hust.	-	+	-	-
Nitzschia panduriformis var. *minor* Grun.	-	+	-	-
Nitzschia apiculata (Greg.) Grun.	-	+	-	-
Nitzschia fusoides nov.	-	+	-	-
Nitzschia lorenziana Grun.	-	+	-	-
Nitzschia angularis Smith	-	+	-	-
Nitzschia hungarica Grun.	-	-	+	+
Nitzschia longissima (Breb.) Ralf.	+	+	-	-
Nitzschia palea (Kz.) Smith	-	-	+	+
Nitzschia paradoxa (Gmel.) Grun.	+	-	-	-
Nitzschia seriata Cleve	+	+	-	-
Nitzschia sigma Smith	+	+	+	+
Nitzschia sigmoidea (Ehr.) Smith	-	+	+	+
Nitzschia trybionella var. *victoriae* Hantzsch.	-	+	+	+
Planctoniella curvatulus Schut.	+	-	-	-
Pinnularia major (Kz.) Cl.	+	-	-	-
Pinnularia trevelyana (Donk.) Rabh.	+	-	-	-
Pleurosigma angulatum (Quek.) Smith	-	+	-	-
Pleurosigma distortum Smith	-	-	+	-
Pleurosigma aestuarii (Breb.) Smith	+	-	-	-
Pleurosigma decorum Smith	+	-	-	-
Pleurosigma elongatum Smith	+	+	-	-
Pleurosigma obscurum Ehren.	+	-	-	-
Pleurosigma hamulifera	+	-	-	-
Rhabdonema adriaticum Kutz.	-	+	-	-
Rhizosolenia imbericata var. *shrubsolei* Cleve	-	+	+	+
Rhizosolenia robusta Norm.	+	-	-	-
Rhizosolenia setigera (Brigh.)	-	+	+	+
Rhizosolenia calcar Schul.	-	+	-	-
Rhizosolenia alata form *gracillima* Bright.	-	+	-	-
Rhizosolenia stolterfothii Perag.	-	+	-	-
Rhopalodia gibba (Ehr.) O.F. Muller	-	-	+	+
Rhopalodia gibberula (Ehren.) Mull.	-	+	-	-
Skeletonema costatum (Grev.) Cl.	-	+	-	-
Stauroneis anceps Ehren.	-	-	+	+
Striatella unipunctata (Lyng.) Ag.	-	+	-	-
Surirella clypus (Kutz.)	-	-	+	+
Surirella striatula (Kutz.)	-	+	+	+
Surirella fastenasa Greg.	+	-	-	-
Surirella gemma Ehren.	+	-	-	-
Surirella linearis Smith	+	-	-	-
Surirella ovata Kz	-	+	-	-
Synedra acus Kutz.	-	-	+	+
Synedra crystallina (Lyng.) Kutz.	-	+	-	-
Synedra laevigata Ehren.	-	+	-	-
Synedra tabulata Hust.	-	-	+	+
Synedra ulna var. *amphizhynous*	-	-	+	+

Species	Fouda *et al.* (1985)	Taha (1990)	Shabana (1999)	Touliabah *et al.* (2002)
Synedra ulna (Nitz.) Ehren.	+	-	+	+
Synedra undulata (Baily) Greg.	+	+	-	-
Thalassionema nitzschioides (Grun.) Hust.	+	+	+	+
Thalassiosira excentrica (Ehren.) Cleve	-	-	+	+
Thalassiothrix longissima Cl. & Grun.	+	-	-	-
Thalassiothrix ratula Bail.	+	-	-	-
Thalassiothrix frauenfeldii Grun.	-	+	-	-
Tropidoneis lepidoptera (Greg.) Cleve	+	+	-	-
Subtotal of the recorded species	58	85	62	61
Dinophyceae				
Amphidinium spheoides Wulff.	-	-	+	+
Amphisolenia extensa Kofoid.	-	-	+	+
Ceratium egyptiacum Halim	-	+	+	+
Ceratium furca Ehren.	+	+	+	+
Ceratium tripos Nitzsch.	-	+	+	+
Ceratium candelabrum Ehren.	+	-	-	-
Ceratium setaceum	+	-	-	-
Ceratium lineatum (Ehren.) Cl.	+	-	-	-
Ceratium pentagonum Gour.	+	+	-	-
Ceratium fusus var. *seta* Ehren.	-	+	-	-
Ceratium kofoidii Jorgen.	-	+	-	-
Dinophysis caudata Saville-Kent	+	+	+	+
Dinophysis tripos Gourret	+	+	-	-
Diplopsalis lenticula Bergh.	+	+	+	+
Exuviaella apora Schiller	-	+	+	+
Exuviaella compressum Ostr.	-	-	+	+
Exuviaella marina Ceink	-	+	-	-
Exuviaella sp.	+	-	-	-
Gonyaulax apiculata (Penard) Entz.	-	-	+	+
Gonyaulax monocantha Pav.	-	+	-	-
Gonyaulax spinifera Clap and Lach	-	+	-	-
Gymnodinium gibberum Schilling	-	-	+	+
Gymnodinium lunula Schut.	+	-	-	-
Gymnodinium palustre Schilling	-	-	+	+
Gymnodinium simile Skuja	-	+	-	-
Gymnodinium sp.	-	+	-	-
Gymnodinium splendens Labour	-	-	+	+
Heterodinium mediterraneum	+	-	-	-
Oxyrrhis marina Duj.	-	+	-	-
Oxytoxum mitra (Stein) Schiller	-	-	+	+
Oxytoxum sceptrum (Stein) Schioder	-	+	+	+
Oxytoxum variabile Schiller	-	-	+	+
Parella globules	+	-	-	-
Phalacroma circumsutum Gom.	+	-	-	-
Peridinium cerasus Paulsen.	-	+	+	+
Peridinium divergens (Ehren.)	+	+	+	+
Peridinium pulchellum (Ehren.)	-	-	+	+
Peridinium trochoidium (Stein) Lemm.	-	+	+	+
Peridinium granii Osten.	+	+	-	-
Peridinium globulum Geit	+	-	-	-
Peridinium excentricum Skuja	+	-	-	-
Peridinium irochi	+	-	-	-
Peridinium breve Ehren.	+	-	-	-
Peridinium depressum Bailey	+	+	-	-

Species	Fouda *et al.* (1985)	Taha (1990)	Shabana (1999)	Touliabah *et al.* (2002)
Peridinium diabolus **Cleve**	+	+	-	-
Peridinium pellucidum **(Bergh.) Schult**	-	+	-	-
Peridinium achromaticum **Levan.**	-	+	-	-
Peridinium inconspicuum **Lemm.**	-	+	-	-
Prorocentrum micans **(Ehren.)**	+	+	+	+
Prorocentrum scutellum **Schroed**	+	-	+	+
Prorocentrum splendens **Lebour**	-	-	-	+
Protoceratium reticulatum	+	-	-	-
Pyrocystis fusiformis **Murray**	+	-	-	-
Subtotal of the recorded species	**25**	**28**	**22**	**23**
Cyanophyceae				
Anabaena bergii **Osten.**	-	-	+	+
Chroococcus turgidus **(Kutzing) Nageli**	-	+	+	+
Lyngbya martensiana **Meneghini**	+	-	-	-
Merismopedia **sp.**	+	-	-	-
Gomphosphaeria aponiana **Kutz.**	-	+	-	-
Nodularia fusca **Mertens**	-	+	-	-
Oscillatoria boryana **(Ag.) Bory**	+	-	-	-
Oscillatoria geminata **(Meneg.) Gom.**	-	-	+	+
Oscillatoria planctonica **Wolosz**	-	-	+	+
Oscillatoria subulifemis **Kutz.**	-	-	+	+
Oscillatoria **sp.**	-	+	-	-
Spirulina subtilissima **Kutz.**	-	+	+	+
Spirulina subsala **Oerst.**	-	+	-	-
Spirulina **sp.**	+	-	-	-
Tetrapedia reinschiana **Archer**	-	-	+	+
Subtotal of the recorded species	**4**	**6**	**7**	**7**
Cryptophyceae				
Rhodomonas minuta **Skuja**	-	-	+	+
Euglenophyceae				
Euglena viridis **Ehrenberg**	-	-	+	_
Subtotal of the recorded species	**0**	**0**	**2**	**1**
Chlorophyceae				
Carteria cardiformis **(Carter) Dill**	-	-	+	+
Chlamydomonas **sp.**	-	-	+	+
Cladophora crispata **(Roth.)Kutz.**	-	-	+	+
Dunaliella bardawillii **Halim**	-	-	+	+
Dunaliella salina **Dunal.**	-	-	+	+
Zygnema **spp.**	+	-	-	-
Subtotal of the recorded species	**3**	**0**	**5**	**5**
Chrysophyta				
Chromulina globosa **Pascher**	-	-	+	+
Dictyocha fibula **Ehren.**	-	-	+	+
Dictyocha speculum **(Ehren.) Haecke**	-	-	+	+
Distephanus octonarius **(Ehren.) Def.**	-	-	+	+
Subtotal of the recorded species	**0**	**0**	**4**	**4**
Total species	**90**	**119**	**102**	**101**

5.1.2 Density and Biomass

Taha (1990) studied the fluctuation of the phytoplankton density in the lagoon for two successive years; 1987 and 1988, at 12 stations (Fig. 5.3). The

data revealed that the mean phytoplankton standing crop in the two basins of the lagoon were nearly similar. According to the annual average of the phytoplankton abundance, the phytoplankton density during 1988 was higher than 1987. The increase in phytoplankton abundance during 1988 was obvious only during summer at the stations close to the two inlets (Mid of El-Telul, Inlet I and North of Rwak); such flourishing of phytoplankton standing crop was not detected in the rest of the year. This flourishing was accompanied with the increase of NH_4, NO_3, PO_4, T.N. (total nitrogen) and T.P. (total phosphorus) by 2-6 folds, while there were reduction in both salinity and NO_2. This confirmed the results of Ibrahim *et al.* (1986), who conducted small-scale experiments with the lagoon waters to investigate the effect of nitrogen and phosphorus additions on the phytoplankton primary production. They found that the maximum primary productivity was attained when nitrogen and phosphorus were added together. This suggested that the addition of 0.225 mg nitrate-nitrogen and 0.15 mg phosphate-phosphorus to one liter of the lagoon water increased productivity 7 times. Taha (1990) indicated that in the eastern basin, the phytoplankton standing crop at the inlet point (Boughaze II) was higher than most stations except Mid of El-Telul.

Table 5.2. **Phytoplankton abundance (No. of cells x 10^2 L^{-1}) at Bardawil Lagoon During 1997 (Shabana 1999)**

Stations	Feb	Apr	Jun	Aug.	Oct	Dec	Average
Rabaa (XII)	2.98	3.30	1.65	2.91	2.87	2.20	2.65
Boughaze 1(X)	2.46	3.21	2.20	2.93	2.87	2.48	2.69
El-Kals (VII)	3.07	2.85	2.08	2.48	2.08	2.63	2.53
Boughaze II (IV)	2.54	2.01	2.20	2.35	1.48	1.39	1.99
El-Telul (I)	1.79	1.92	2.20	2.03	1.38	3.56	2.15
Zaranik (III)	1.95	1.95	2.20	2.17	1.24	2.88	2.06
Average	2.46	2.54	2.09	2.48	1.99	2.52	2.35

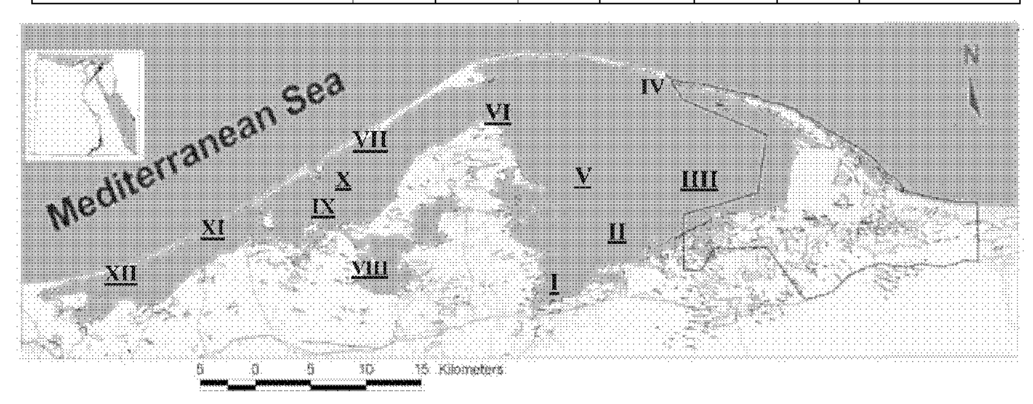


Fig. 5.1. **Map of the northern side of Sinai showing the location of the Bardawil Lagoon and the selected stations (Abd El-Karim *et al.* 2006)**

Table 5.3. **Phytoplankton abundance (No. of cells x 10^2 L^{-1}) at Bardawil Lagoon during 1987/88 (Taha 1990).**

Stations	Spring 1987	Summer 1987	Autumn 1987	Winter 1988	Spring 1988	Summer 1988	Autumn 1988	Winter 1989	Average
El-Telul (I)	87	138	66	220	79	286	688	99	207.9
East of El-Telul (II)	104	500	24	89	9	6024	55	329	891.8
El-Zaranik (III)	93	295	180	30	14	642	107	296	207.1
Boughaze II (IV)	79	722	88	115	24	498	246	292	258
West of El- Telul (V)	56	91	476	82	71	218	83	480	194.6
El-Kals (VII)	464	17	196	14	444	73	983	1669	482.5
El-Rowak (VIII)	103	11	30	32	89	296	30	64	81.9
N. of El-Rowak (IX)	27	539	82	49	12	2670	91	753	527.9
Boughaze I (X)	23	394	420	22	335	1913	84	316	438.4
El- Nasr (XI)	162	276	76	16	77	389	318	186	187.5
Nigelah	142	1595	68	33	268	68	1094	140	426
Rabaa (XII)	115	217	104	54	1707	98	423	119	354.6
Average	121.3	399.6	150.8	63.0	260.8	1097.9	350.2	395.3	354.9

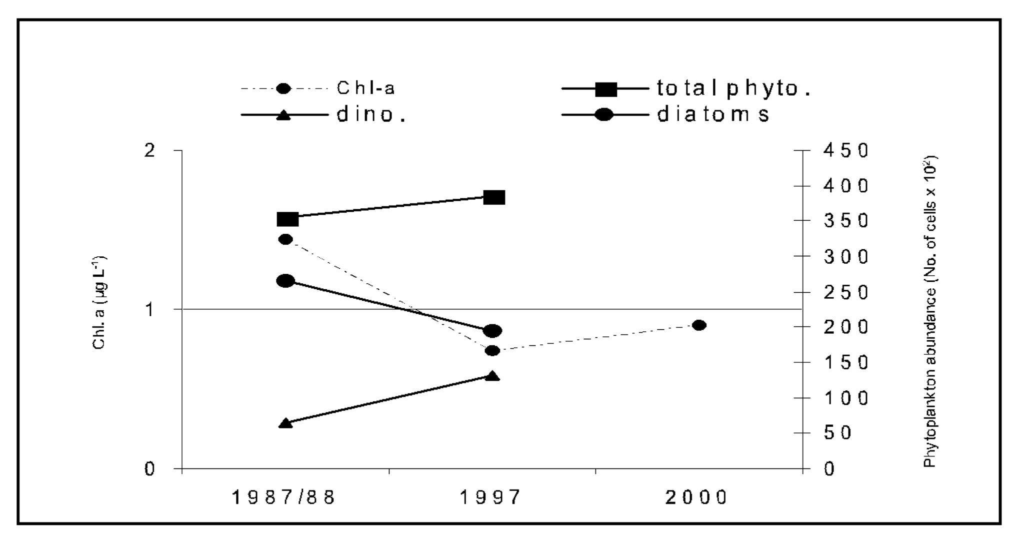


Fig.5.2 **Changes of phytoplankton groups and chl *a* from 1987 to 2000**

Similarly, the phytoplankton abundance at the inlet 1 (Boughaze I) was higher than most stations except at El-Kals and North of El-Rowak. This may be due to the antagonistic effect of both salinity and nutrients; which one is

more effective, depending on the distance from the inlets. At the stations far away from the inlets , at El-Nasr, Rabaa, Nigelah, El-Telul, El-Zaranik and West of El-Telul, the negative effect of salinity is more pronounced compared with the positive effects of the high nutrients concentrations. Meanwhile, at the stations close to the inlets point, Mid of El-Telul, El-Kals and North of El-Rowak, the positive effects of the high nutrient levels was more observed than the negative effect of salinity. The annual average standing crop of phytoplankton during 1997 (Shabana 1999, Table 5. 2) was nearly twice the corresponding values during 1978/88.

5.1.2.1 Diatoms

During the period from 1969 till 2002, diatoms were the most important group in Bardawil Lagoon. It constituted more than 60% of the total phytoplankton species and 30% of its density. As shown in Fig. (5.3) and Table (5.1), the least number of diatomic species (58 species) was recorded by Fouda *et al.* (1985), while the highest number (85 species) was recorded by Taha (1990) in 1987/88. During the recent studies of Shabana (1999) in 1997 and Touliabah *et al.* (2002) in 2000, the recorded species dropped to 62 species. It may be noted that, among the recorded 159 diatomic species there were only 7 species common among the different investigations. This may be attributed to changes in the lake environment, or to misidentification among them.

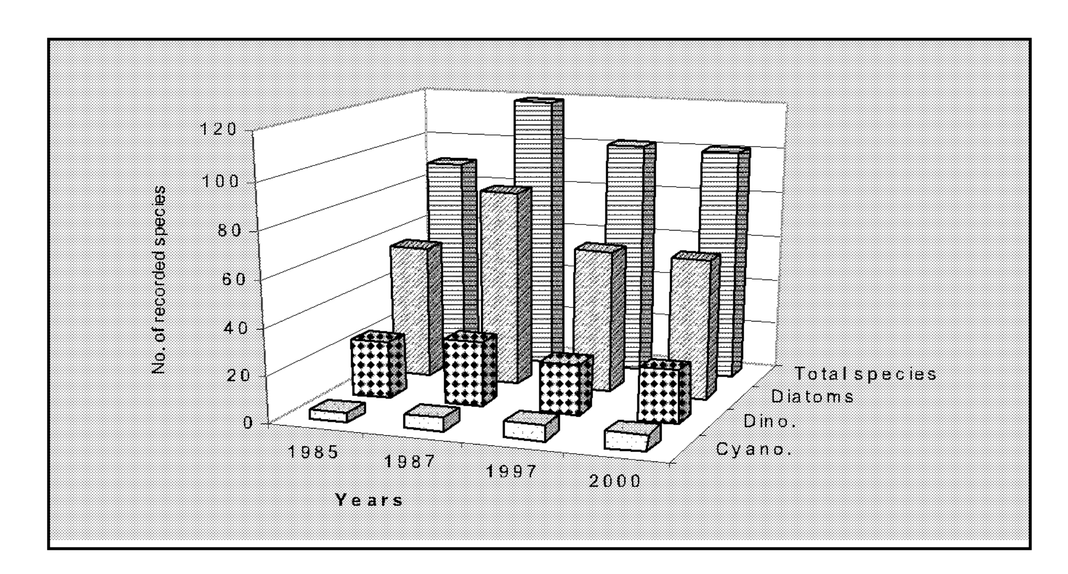


Fig. 5.3. **No. of recorded phytoplankton species in Bardawil Lagoon during the period from 1985 – 2000**

Diatoms of Bardawil Lagoon are composed mainly of typically oligotrophic forms. The pinnate forms as *Campylostylus striatus, Nitzschia* spp.,

Cocconeis spp. and *Licmophora flabellata* were the most abundant species of Bacillariales. According to Ehrlich (1975) the diatoms assemblages recorded from the surface sediment of Lake Bardawil were composed of marine euryhaline and holoeuryhaline forms, while near the artificial inlets there were marine stenohaline species. It may be noted that most of species listed by Ehrlich (1975) were recorded by most investigators and the planktonic forms in the lagoon water were very rare. Kimor & Berdugo (1969) recognized several species of diatoms in Lake Bardawil, among them *Synedra hennedyana, S. gaillonii and S. undulata*. The species *Campylostylus striatus* was found in high salinity areas of over 70 ‰. In the recent studies, this species was found in most sites of the lagoon and gradually increased in its abundance. Fouda *et al.* (1985) documented 99 phytoplanktonic species in Bardawil Lagoon; 66 diatom species were found, and the most abundant genera were *Amphora, Pleurosigma, Coscinodiscus, Chaetoceros* and *Surirella*. *Amphora ovalis* was the dominant species. Species of the genera *Gyrosigma, Synedra* and *Thalassiothrix* were present in considerable quantities. Ehrlich (1975) identified many diatoms that were not mentioned in Fouda's study (1985), such as *Cocconeis bardawilensis, Amphora coffaeiformis, Nitzschia frustulum* and *Rhopalodia gibberula*. In 1987/1988, Taha (1990) identified 85 diatom species; *Campylostylus striatus, Cocconeis* spp., *Rhizosolenia setigera, Nitzschia* spp. and *Licmophora flabellata* were the most abudant.

Comparing the recent studies reported by Shabana (1999), and Touliabah *et al.* (2002) with the data of Taha (1990) (Table 5. 4), it was found that *Campylostylus striatus* became a perennial species and was the most abundant diatom in all stations of the lagoon (Table 5. 5). This species prefers unpolluted water and has been used as an indicator of oligotrophic or beta-mesotrophic conditions (Kolwitz & Marsson 1950). Moreover, the species *Fragilaria crotonensis, Licmophora flabellata, Cocconeis bardawilensis* and *Synedra* sp. became more abundant species. On the other side, the Nitzschiaceae species decreased in number and density.

Taha (1990) showed that the diatoms group was the dominant one, comprising 36.1 to 72.1% of the total phytoplankton standing crop (Table 5.6). The highest record of bacillariophytes (average of 954 x 10^2 cells L^{-1}) was in summer 1988 (as responsible for the high increase of total phytoplankton standing crop during this year), whereas the least (43 x 10^2 cells L^{-1}) prevailed in winter 1988. Similar results were obtained by Shabana (1999) (Table 5.7) who postulated that diatoms were a dominant group and its climax was found during summer. The eastern basin was richer than the western one. In the eastern basin, the water was more productive than Boughaze II, while the opposite was found in the western basin. In average, the two inlets were more productive than the lagoon. The flourishing of diatoms during 1988 was

attributed to blooming of *Campylostylus striatus* and *Thalassionema nitzschioides*.

Table 5.4. **Abundance (No. of cells L^{-1}) of the most important diatom species in Bardawil Lagoon during 1987/88 (Taha 1990)**

Species	Spring 1987	Summer 1987	Autumn 1987	Winter 1988	Spring 1988	Summer 1988	Autumn 1988	Winter 1989
Thalassiosira nitzschiodes	27	18833	68	51	93	483	6783	83
Campylostylus striatus	132	1257	240	115	27	217	1685	67
Cocconeis bardawilensis	473	130	307	48	1462	310	517	567
Cocconeis scutellum	525	82	498	213	687	7	23	133
Rhizosolenia setigera	3	7	3	10	3	72200	3	3000
Nitzschia closterium	33	13	147	111	27	1273	75	12
Gyrosigma acuminatum v. *balticum*	42	40	53	58	62	3	8	67
Nitzschia sigma	9	217	305	221	58	155	393	176
Nitzschia longissima	44	68	168	17	188	968	142	8
Licmophora flabellata	0	20	107	114	142	100	707	17

Bardawil Lagoon during 1987/88 (Taha 1990)

Table 5.5. **Abundance (No. of cells L^{-1}) of the most important diatom species in Bardawil Lagoon during 1997 (Shabana 1999)**

Species	Feb.	April	Jun	Aug.	Oct.	Dec.
Fragilaria crotonensis	266.7	133.3	400.0	1066.7	0	133.3
Synedra tabulata (Ag.) Kutz.	133.3	133.3	133.3	0	133.3	200.0
Synedra ulna	66.7	66.7	0	333.3	133.3	66.7
Licmophora flabellata (Gran.) Ag.	133.3	0	200.0	1200.0	66.7	333.3
Campylostylus striatus Shadbolt	533.3	133.3	200.0	1266.7	933.3	666.7
Cocconeis bardawillensis Ehren.	133.3	333.3	133.3	133.3	133.3	266.7
Surirella striatula (Kutz.)	133.3	133.3	0	200.0	66.7	66.7

Table 5.6. **Seasonal variations of the diatoms abundance (No. of cells x 10^2 L^{-1}) in Bardawil Lagoon during 1987/1988 (Taha 1990)**

Stations	Spring 1987	Summer 1987	Autumn 1987	Winter 1988	Spring 1988	Summer 1988	Autumn 1988	Winter 1989	Average
El-Telul (I)	72	55	62	154	34	61	418	79	116.98
East of El-Telul (II)	80	291	20	15	2	6022	42	271	842.98
El-Zaranik (III)	76	44	100	14	4	69	34	236	72.1
Boughaze II (IV)	68	666	60	109	5	318	173	212	201.48
West of El- Telul (V)	5	59	447	78	27	100	79	102	112.1
El-Kals (VII)	11	14	160	12	373	57	975	1463	383.1
El-Rowak (VIII)	60	3	18	10	39	19	20	23	24.0
N. of El-Rowak (IX)	17	512	28	41	7	2643	58	733	504.98
Boughaze I (X)	12	373	280	18	12	1813	56	286	356.35
El- Nasr (XI)	68	222	60	12	14	299	150	151	122.0
Nigelah	83	450	46	6	122	35	1025	24	223.98
Rabaa (XII)	91	16	84	50	568	12	11	66	112.35
Average	53.6	225.4	113.8	43.3	100.6	954.0	253.4	303.8	256.0

Table 5. 7. **Seasonal variations of the diatoms abundance (No. of cells x 10^2 L^{-1}) in Bardawil Lagoon during 1987/1988 (Shabana 1999)**

Stations	Feb.	April	Jun	August	Oct	Dec	Average
Rabaa (XII)	260	320	60	440	500	120	283.3
Boughaze I(X)	100	260	20	360	200	420	226.7
El-Kals (VII)	340	260	60	220	40	220	190.0
Boughaze II (IV)	140	100	100	180	60	60	106.7
El-Telul (I)	60	140	100	240	40	980	260.00
Zaranik (III)	60	100	100	180	80	100	103.3
Average	160.0	196.7	73.3	270.0	153.3	316.7	195.0

5.1.2.2 Dinoflagellates

Dinoflagellates group ranked the second in predominance position, where the number of species ranged between 22 and 28 in the period of 1985-2002 (Table, 5.1). The species of the genera *Peridinium* and *Ceratium* have been recorded in most of planktonic samples. The dominant species were *Peridinium granii*, *P. divergens* and *Ceratium furca* (Fouda *et al.* 1985). Kimor (1975) found that the three species *Ceratium furca*, *C. fusus* and *C. egyptiacum* were perennial elements in plankton; sometimes reaching to considerable proportion of the total phytoplankton. Fouda *et al.* (1985) did not record *C. egyptiacum* at the lagoon, while Taha (1990) and Shabana (1999) recorded the species *Diplopsalis lenticula* and *Dinophysis tripos* in considerable numbers. The species *Protoceratium reticulatum*, *Parella globulusa* and *Peridinium diabolus* were found only at Raabaha, El Rewak and Boughaze II, respectively.

Taha (1990) recorded 28 dinoflagellates species, belonging to 10 genera and 5 families (Table 5.1). She concluded that *Prorocentrum mechanis*, *Exuviaella apora*, *E. marina*, *Peridinium divergens*, *P. trochoidium*, *Ceratium furca* and *Diplopsalis lenticula* were the most important dinoflagellate species. Shabana (1999) identified 22 species during 1997 (Table 5.1); some of them were recorded for the first time (*Oxytoxum mitra*, *O. variabile*, *Gonyaulux apiculata*, *Amphidinium spheoides*, *Amphisolenia extensa* and *Gymnodinium splendens*). *Peridinium trochoidium* was perennial species, *Prorocentrum micans*, *P. scutellum* and *Gymnodinium splendens* were very abundant. Many of the recorded species are known as toxic forms; among of them the *Oxytoxum* spp. Comparing the data of the studies of Taha (1990) and Shabana (1999) revealed that there were great differences in the dominant species, as only two species were common in the two studies. Touliabah *et al.* (2002) reported that dinoflagellate species constituted about 22% of total phytoplankton species. They postulated that *Peridinium trochoidium*, *P. divergens*, *P. pulchellum*, *P. cerasus*, *Prorocentrum scutellum*, *P. micans* and *P. splendens* were more abundant.

Table 5.8. **Abundance (No. of cells L-1) of the most important dinoflagellate species in Bardawil Lagoon during 1997 (Shabana 1999)**

	Feb.	April	Jun	August	Oct	Dec
Exuviaella compressum Ostef.	66.67	66.67	0.00	133.33	133.33	200.00
Prorocentrum micans (Ehren.)	466.67	0.00	800.00	400.00	466.67	200.00
Peridinium trochoidium (Stein) Lemm.	466.67	400.00	466.67	466.67	533.33	66.67
Gymnodinium gibberum Schiller	133.33	66.67	133.33	266.67	266.67	66.67
Perdinium cerasus Paulsen.	133.33	66.67	133.33	266.67	266.67	66.67
Ceratium tripos Nitzsch.	66.67	66.67	66.67	133.33	66.67	66.67

Table 5.9. **Abundance (No. of cells L^{-1}) of the most important dinoflagellates species in Bardawil Lagoon during 1987/88 (Taha 1990).**

Species	Spring 1987	Summer 1987	Autumn 1987	Winter 1988	Spring 1988	Summer 1988	Autumn 1988	Winter 1989
Prorocentrum mecanis	810	440	1100	800	700	2100	1200	5500
Exuciella apora	920	340	500	900	200	100	100	200
E. marina	520	100	300	100	1200	100	100	150
Peridinium divergens	1010	890	400	100	5100	700	800	300
P. trochoidium	540	220	200	100	5000	500	2600	100
Ceracium furca	0	320	900	200	200	300	100	0
Dinophysis lenticula	200	200	400	100	200	200	300	100

Taha (1990) indicated that members of this class occupy the second predominance position of phytoplankton in Bardawil Lagoon (Tables 5.9 and 5.10). Only, in spring 1988, they dominated the other classes. The highest population density of dinophytes (average 159.6 x 10^2 cells L^{-1}) was recorded in spring 1988, while the minimum one (17.3 x 10 ^{2} cells L^{-1}) was observed in winter. Most of the lowest values were recorded at the eastern basin, where the least one of 2 x 10^2 cells L^{-1} was found at El-Kals during winter 1988. On the other hand, most of the maximum readings were recorded in the western basin, where the highest value of 1139 x L^{-1} was documented at Rabaa during spring 1988.The lowest average population density of dinophytes was recorded in the eastern basin with an average of 46.43 x 10^2 cells L^{-1}, then increased to reach an average of 50.06 x 10^2 cells L^{-1} at the inlets, and reached its climax of 88.43 x 10^2 cells L^{-1} in the western basin. Comparing the study of Taha (1990) in 1987/1988 with that of Shabana (1999) (Tables 5.8 and 5.11) during 1997, it was found that the annual mean density of dinophytes was doubled (Tables 5.10 & 5.11).

5.1.2.3 Cyanophyceae

This group is sporadic and scarce in Bardawil Lagoon; it was irregularly distributed. Since Kimor (1975) study on the lagoon phytoplankton, the total cyanophytes recorded by the different authors did not exceed 15 species. The highest number reported was 7 species by both Shabana (1999) and Touliabah *et al.* (2002). Kimor (1975) identified two coccoid species; *Chroococcus*

turgidus and *Gomphosphaeria aponiana*. Fouda *et al.* (1985) found only one coccoid (*Merismopedia* sp.) and three filamentous non-heterocystus species belonging to Oscillatoriales (*Lyngbya martensiana*, *Oscillatoria boryana* and *Spirulina* sp.). Taha (1990) reported that six cyanophytes were identified; two coccoids and four filamentous non-heterocystus belonging to Oscillatoriales; *Nodularia fusca* and *Gomphosphaeria aponiana* were the most important species. The first heterocystus blue-green alga (*Anabaena borgii*) was recorded by Shabana (1999) and Touliabah *et al.* (2002).

Table 5.10. **Seasonal variations of the dinoflagellates abundance (No. of cells x 10^2 L^{-1}) in Bardawil Lagoon during 1987/88 (Taha 1990)**

Stations	Spring 1987	Summer 1987	Autumn 1987	Winter 1988	Spring 1988	Summer 1988	Autumn 1988	Winter 1989	Average
El-Telul (I)	13	9	4	56	45	30	270	20	55.9
East of El-Telul (II)	20	34	4	74	7	2	13	58	26.5
El-Zaranik (III)	14	68	80	16	10	12	18	60	34.8
Boughaze II (IV)	10	6	28	6	19	58	25	80	29.0
West of El- Telul (V)	51	4	29	4	44	118	4	378	79.0
El-Kals (VII)	15	3	36	2	71	13	8	140	36.0
El-Rowak (VIII)	42	8	12	2	50	277	10	41	55.3
N. of El-Rowak (IX)	8	27	54	8	5	27	10	20	19.9
Boughaze I (X)	11	21	140	4	323	20	20	30	71.1
El- Nasr (XI)	94	54	16	4	63	37	168	35	58.9
Nigelah	56	145	22	27	139	21	69	116	74.4
Rabaa (XII)	24	201	20	4	1139	34	412	36	233.8
Average	29.8	48.3	37.1	17.3	159.6	54.1	85.6	84.5	64.5

Table 5.11. **Seasonal variations of the dinoflagellates abundance (No. of cells x 10^2 L^{-1}) in Bardawil Lagoon during 1997 (Shabana 1990)**

Stations	Feb.	April	Jun	August	Oct	Dec	Average
Rabaa (XII)	160	200	260	260	180	40	183.3
Boughaze I(X)	120	140	140	360	200	80	173.3
El-Kals (VII)	260	160	100	100	120	60	133.3
Boughaze II (IV)	120	240	80	180	80	20	120.0
El-Telul (I)	60	160	80	140	40	80	93.3
Zaranik (III)	80	40	80	100	40	220	93.3
Average	133.3	156.7	123.3	190.0	110.0	83.3	132.8

Chlorophyll *a*

Chlorophyll *a* is a good indicator for phytoplankton biomass. The majority of chlorophyll *a* values during the study of Taha (1990) were lower than 1 µg L^{-1} (Table 5.12), moreover; most of the readings obtained by Shabana (1999) and Touliabah *et al.* (2002) were very low to the undetectable limits. These values indicate, to some extent, that Bardawil Lagoon is a very oligotrophic ecosystem. In contrast to the phytoplankton standing crop data, the figures of chlorophyll *a* indicated that, the eastern basin is richer than the western one; also, the lagoon was richer during 1988 than 1987. Throughout the

period from 1987 to 2000, the highest chlorophyll *a* values ranged between 11.72 µg L^{-1} (1988) at Mid of El-Telul and 4.3 µg L^{-1} (1999) at Rabaa. On the other side, the least values in the same period ranged between 0.003 µg L^{-1} at Rabaa during 1987 to undetectable levels during 1999 and 2002. The highest average annual chlorophyll *a* (1.44 µg L^{-1}) was recorded during 1987/88 by Taha (1990), and declined to 0.74 µg L^{-1} during 1998 by Shabana (1999) and marginally reinceased to 0.9 µgL^{-1} during 2000 (Touliabah *et al.* 2002). These differences in chlorophyll *a* values among the different authors may not be attributed reliably to environmental changes in the lagoon, but to the different methods used to detect chl. *a*. Taha (1990) used the florometric method to measure chl. *a*, which is more accurate and can detect chlorophyll *a* values till 0.001 µg L^{-1}, while both Shabana (1999) and Touliabah *et al.* (2002) used the spectrophotometric method.

***Table 5.12.* Seasonal variations of the Chlorophyll *a* values (µg L^{-1}) in Bardawil Lagoon (Taha 1990)**

Stations	Spring 1987	Summer 1987	Autumn 1987	Winter 1988	Spring 1988	Summer 1988	Autumn 1988	Winter 1989	Average
El-Telul (I)	0.06	3.06	0.51	0.04	1.55	0.36	0.76	5.33	1.46
East of El-Telul (II)	0.04	0.54	0.14	0.01	0.47	0.36	0.43	11.72	1.71
El-Zaranik (III)	0.04	0.37	0.44	0.01	0.82	0.31	0.46	6.54	1.12
Boughaze II (IV)	0.03	0.32	0.34	0.02	0.96	0.44	0.87	6.06	1.12
West of El-Telul (V)	0.01	0.36	1.68	0.12	1.44	0.22	0.37	5.46	1.21
El-Kals (VII)	0.01	0.36	0.54	0.01	0.71	0.12	0.4	4.92	0.88
El-Rowak (VIII)	0.00	0.45	0.35	0.02	0.72	0.34	0.2	2.39	0.56
N. of El-Rowak (IX)	0.01	0.51	0.32	0.01	0.51	0.52	0.87	1.81	0.57
Boughaze I (X)	0.01	0.41	1.68	0.02	0.85	0.68	1.15	3.31	1.01
El- Nasr (XI)	0.01	0.59	0.31	0.00	0.71	0.41	1.08	0.43	0.44
Nigelah	0.01	0.58	0.44	0.01	0.76	0.79	1.89	3.81	1.04
Rabaa (XII)	0.01	0.9	0.36	0.00	1.23	0.63	1.89	4.13	1.144
Average	0.02	0.70	0.59	0.02	0.89	0.43	0.86	4.65	1.02

5.2 PERIPHYTIC ALGAE

In aquatic ecosystems, especially freshwater ones, a considerable attention has been directed to periphyton in the past two decades, to investigate their role in water production and their contribution to both pelagic and littoral food webs, mobilizing the nutrient to the pelagic poor water, and using them as ecological indicators.

The importance of periphyton, especially those that colonize aquatic macrophytes, is now clear in its contribution to the primary production of the

ecosystem, and it represents a readily available food base for many invertebrates, waterfowl and fish (Van Donk *et al.* 1994). Therefore, a more extensive knowledge of periphyton is essential to understand aquatic food webs, for water plant management, and also ecological changes (Engle & Melack 1990).

In Bardawil Lagoon, although its shallowness and the intensive light that penetrates the water column, reaching the surface sediment most of the year, there was scarce investigations devoted to study the periphytic communities of the lagoon, e.g. that of Ehrlich (1975), who studied the surface sediment epipelic diatoms.

5.2.1 Epiphytic Algae

The study of Abd El-Karim & Hassan (2006) is the only known investigation dealing with the epiphytic communities in Bardawil Lagoon. They studied epiphytic communities of both plants *Cymodocea nodosa* (Ucria) Ascherson and *Ruppia cirrhosa* (Petagna) Grande, and recorded 121 species belonging to 42 genera and 3 classes (Table 5.13). Many of these species are known as attached species in both marine and fresh waters, as *Mastoglioa* spp., *Achnanthes* spp., *Amphora* spp., *Navicula* spp., *Cocconeis* spp., *Nitzschia* spp., *Diploneis* spp., *Pleurosigma* spp., *Rhopalodia* spp., *Chroococcus* spp., *Gomphosphaeria* spp., *Lingbya* spp. *and Oscillatoria* sp. 99 diatom species represent 77.86% of the total number of epiphytes species were recorded. The diatom species *Liolima pacificum*, *Mastogloia pumilla*, *Navicula atomus Nitzschia punctata*, *Rhopalodia gibba*, *Thalassionema frauenfeldii* and *T. nitzschioides* represented more than 67% of the annual average diatoms standing crop. *Rhopalodia gibba* and *Nitzschia punctata* were dominant at Inlet I and NW El-Rowak, while *Thalassionema frauenfeldii* and *T. nitzschioides* flourished in Zaranik, Rowak and Rabaa, but *Liolima pacificum*, *Navicula atomus* were more abundant at El-Rowak. On the other hand, the cyanophytes *Oscillatoria prolifica* and *O. formosa* constituted more than 83.78% of the total annual average cyanophytes standing crop.

5.2.1.1 Epiphytes biodiversity

The study of Abd El-Karim *et al.* (2006) revealed that the diversity values of epiphytes are very low compared with that of phytoplankton. This may be attributed to the high densities of epiphyte species. Table 5.14 shows that the eastern basin is more diverse than both the western one and Boughaze I, respectively. The regional average highest value was 2.17 at NW El-Rowak and the lowest was 1.5 at El-Rowak.

5.2.1.2 Epiphytes abundance

The maximum total epiphytes values were recorded during summer, except at NW El-Rowak station, where maximum values were recorded during winter. On the other side, the minimum values were noted during autumn in the

western basin, while in the eastern one the minimum abundance was measured during winter. The highest epiphytes standing crop of 23751.7 x 10^4/ g dr wt was reported at El-Rowak during summer, while the lowest one (1553.8 x 10^4/ g dr wt) was found at Mid El- Telul during autumn.

Table 5. 13. **Epiphytic species recorded from Bardawil Lagoon (No. of cells x 10^4/gm dr wt sea grass) during 2004 (Abd El-Karim & Hassan 2006).**

Species	Mean	Species	Mean
Bacillariophyceae			
Achnanthes taeniata **Grun.**	**24.00**	***Mastogloia lanceolata*** **Thw.**	**53.61**
Amphiprora alata (Kutz.)	**1.26**	***Mastogloia pumila*** **(Grun.) Cl.**	**689.81**
Amphiprora gigantean **Grun**	**0.69**	***Mastogloia smithii*** **Grun.**	**40.35**
Amphora coffaeiformis **Ag.**	**2.74**	***Melosira moniliformis*** **(Mull.) Ag.**	**1.71**
Amphora holsatica **Hust**	**6.86**	***Melosira jurgensii*** **Ag.**	**2.86**
Amphora ovalis **Kutz.**	**2.97**	***Melosira*** **sp.**	**0.01**
Amphora perpusilla **Grun.**	**23.66**	***Navicula scutiformis*** **Grun.**	**147.79**
Amphora **sp.**	**1.94**	***Navicula angulosa*** **Greg.**	**0.01**
Amphora submontana **Hust.**	**5.37**	***Navicula atomus*** **Naeg.**	**486.36**
Biddulphia aurita **(Lyngb.) Breb.**	**1.14**	***Navicula cryptolyra*** **Ehren.**	**32.58**
Campylodiscus **sp.**	**0.69**	***Navicula delicatula***	**4.57**
Climacosphenia moniligera	**40.01**	***Navicula detenta***	**1.26**
Cocconeis calcar **(Cl.) Cl.**	**1.83**	***Navicula directa*** **Smith**	**1.26**
Cocconeis dirupta **Greg.**	**7.89**	***Navicula gracilis*** **Ehren.**	**9.60**
Cocconeis scutellum Ehren	**2.51**	***Navicula kutzingii*** **Grun.**	**1.37**
Coscinodiscus clypeus **Ehren.**	**0.57**	***Navicula lanceolata*** **(Ag.) Kz.**	**0.69**
Coscinodiscus noricus **Ehren.**	**0.57**	***Navicula lyra*** **Ehren.**	**2.29**
Cyclotella striata **(Kz.) Grun.**	**10.29**	***Navicula perminuta*** **Grun.**	**6.29**
Cyclotella antiqua **Smith**	**1.26**	***Navicula pupula*** **var.** ***minuta*** **V. H.**	**4.00**
Cymbella caespitosa **(Kz.) Brun.**	**0.69**	***Navicula protracta*** **Grun.**	**0.57**
Cymbella micocephala **Grun.**	**12.23**	***Navicula salinarum*** **Grun.**	**0.57**
Diploneis ovalis (Hilse.) **Cleve**	**1.37**	***Navicula cancellata*** **Donkin**	**5.94**
Ezpeitia africana **(Jan. ex Sch.) Fry. & Wat.**	**2.74**	***Nitzschia acicularis*** **W. Sm.**	**1.26**
Ezpeitia barronii **Fry. & Wat**	**0.69**	***Nitzschia angustata*** **(Smith) Grun.**	**5.49**
Fragilaria ritskheri **Carls.**	**0.57**	***Nitzschia closterium*** **Ostr.**	**1.26**
Grammatophora marina **(Lyngb.) Kz.**	**2.29**	***Nitzschia inconspicua***	**40.81**
Campylostylus striatus **Shadbolt**	**93.96**	***Nitzschia lineola*** **Cl.**	**94.53**
Haslea wawrikae **(Hust.) Simon.**	**3.43**	***Nitzschia nana*** **Grun.**	**2.06**
Leptocylindrus danicus **(Celve.)**	**4.11**	***Nitzschia palea*** **(Kz.) W. Sm**	**8.92**
Licmophora anglica	**0.57**	***Nitzschia punctata*** **(Smith) Grun.**	**887.10**
Licmophora flabellata **(Grun.) Ag.**	**80.35**	***Nitzschia sigma*** **Grun.**	**64.47**
Licmophora gracilis **(Ehren.) Grun.**	**24.46**	***Nitzschia sigmoidea*** **(Ehr.) W. Smith**	**6.29**
Licmophora nubecula **(Kz.) Grun.**	**1.26**	***Nitzscia dissipata (Kz.)*** **Grun.**	**4.00**
Licmophora paradoxa **Sm. & Heib.**	**1.14**	***Nitzscia filiformis*** **(Smith) Hust.**	**7.54**
Licmophora **sp.**	**2.06**	***Nitzscia obtusa*** **Smith**	**5.26**
Licmophora tenuis (Kz.) **Grun.**	**3.77**	***Nitzscia ovalis*** **Arnott**	**4.11**
Licmophora tincta **(Ag.) Grun.**	**1.71**	***Nitzscia*** **sp.**	**2.74**
Lioloma pacificum **(Grun.) Hasle**	**565.22**	***Nitzscia trypionella*** **Hant.**	**65.95**

Species	Mean	Species	Mean
Mastogloia angulata Lewis	150.88	*Striatella interrupta (Ehren.)* Heib	14.97
Mastogloia apiculata Smith	204.49	*Striatella unipunctata (*Lyng.*)* Ag.	45.72
Mastogloia braunii Grun	208.26	*Surirella fastuosa* Ehren.	0.69
*Mastogloia elliptica (*Ag.*)* Cl.	73.04	*Tabellaria flocculosa* Huit	127.56
Pleurosigma elongatum Smith	0.57	*Tabellaria fenestrata (*Lyngb.*)* Kz.	2.29
Pleurosigma marinum Donk	4.69	*Thalassionethrix frauenfeldii* Grun.	405.20
Pleurosigma normanii Ralfs	5.14	*Thalassionema nitzschioides (*Grun.*)*	1125.30
Rhopalodia acuminata Krammer	9.49	*Thalassionema bacillare* (Heid. & Kolbe)	295.47
*Rhopalodia gibba (*Ehren.*)* Mull.	467.27	*Thalassiosira allenii* Takano	4.11
Nitzscia vermicularis (Kz.) Grun.	94.64	*Thalassiosrixa* sp.	6.29
Cyanophyceae			
Lingbya limnetica Lemm.	1.23	*Phormidium dictyothallum* Skuja	4.64
Lingbya sp.	109.16	*Phormidium molle (*Kz.*)* Gom.	51.30
Mastigocoleus testarum Lager.	42.86	*Spirulina major* Kz.	6.86
*Oscillatoria prolifica (*Grev.) Gom.	1209.69	*Aphanothece stagnina* (Spren.) Boye-Pet.	0.41
Oscillatoria subbrevis Schm.	58.35	*Chroococcus limneticus* Lemm.	2.29
Oscillatoria Formosa Bory	640.38	*Chroococcus turgidus* (Kz.) Nag.	12.00
Oscillatoria subcapitata Ponom.	65.72	*Gomphosphaeria compacta* (Lem.) Str.	3.28
Dinophyceae			
Gymnodinium simplex (Loh.) Kof.& Swez.	0.57	*Prorocentrum compressum* (Bail) Abe	9.14
Gymnodinium sp.	0.10	*Prorocentrum emarginatum* Fuk.	1.14
Peridenium sp.	0.57	*Prorocentrum lima* (Ehren.) Dod.	11.43
Prorocentrum belizeanum Faust	4.57	*Prorocentrum micans* Ehren.	6.86

Table 5. 14. **Changes of epiphytic species diversity in Bardawil Lagoon (Abd El-Karim & Hassan 2006).**

Stations	Summer	Autumn	Winter	Average
Rabaa (XII)	2.01	2.11	1.76	1.96
Boughaze 1(X)	1.89	1.86	____	1.88
El-Gals (VII)	0.95	0.58	2.98	1.50
Boughaze II (IV)	2.36	1.51	2.65	2.17
El-Telul (I)	1.16	2.13	1.79	1.69
Zaranik (III)	1.43	1.91	2.39	1.91
Average	1.63	1.68	2.31	1.88

The highest regional average value of total epiphytes and their different groups (17085.31 x 10^4/ g dr wt) has been detected at El-Rowak station, while the lowest corresponding value (2494.53 x 10^4/ gdr wt) was measured at Mid El-Telul. The distribution of epiphytic abundance at the different regions of the lagoon can be arranged in the descending order as western basin > eastern basin > Boughaze I (Fig. 5.4)

The highest diatom density values were recorded during summer with a maximum of 23660.94 x 10^4/ g dr wt at El-Rowak station, while the lowest values were noted during autumn, with the lowest value of 1790.39 x 10^4/ g dr wt at El-Rowak. Cyanophytes were not found sometimes at NW El-Rowak and

Inlet I. The maximum blue-greens abundance values were recorded during summer with the highest value of 7466.51 x 10^4/ g dr wt at Rabaa. The highest regional value of 4927.61 x 10^4/ g dr wt was obtained at El-Rowak, while the lowest of 235.06 x 10^4/ g dr wt was reported at Boughaze I. Dinophytes were not recorded at Inlet I and Mid El-Telul, they were always found at Rabaa. The lowest value of 508.36 x 10^4/ g dr wt was detected at El-Rowak during winter. The highest regional value of 186.74 x 10^4/ g dr wt was obtained at El-Rowak.

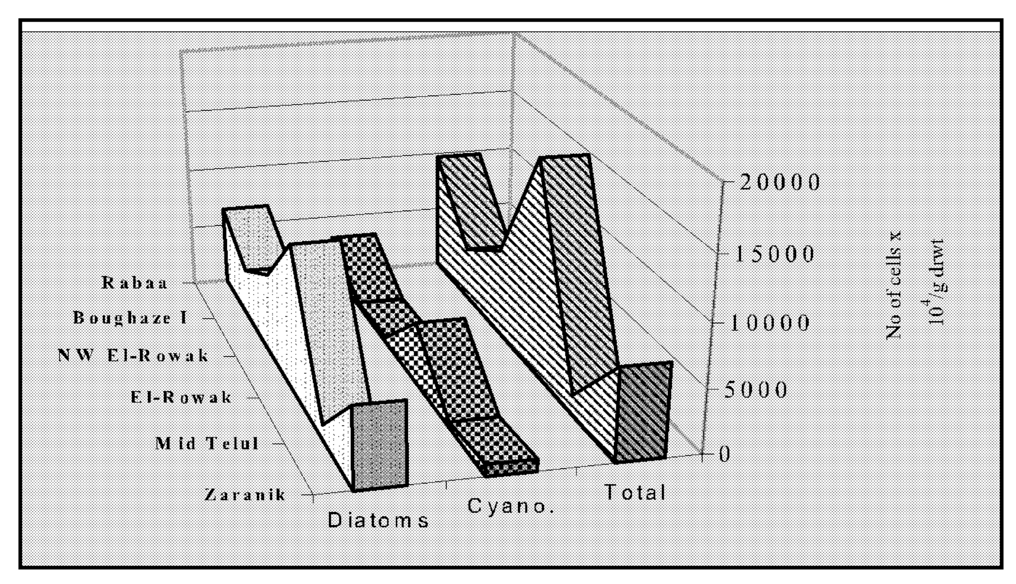


Fig. 5. 4. **Epiphytic distribution of the main algal groups in Bardawil Lagoon during 2004**

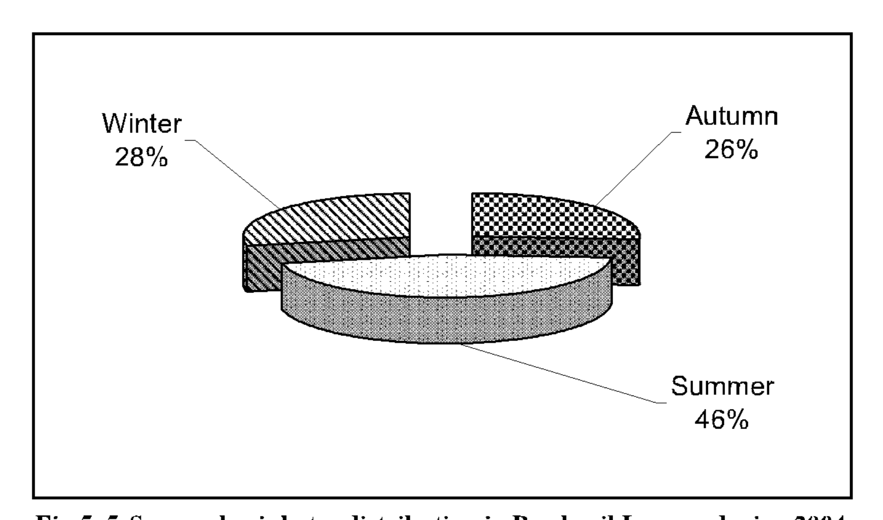


Fig.5. 5. **Seasonal epiphytes distribution in Bardawil Lagoon during 2004**

5.2.1.3 Chlorophyll *a*

The epiphytic algae are very rich in chlorophyll *a* compared with phytoplankton in Bardawil Lagoon. The highest chl *a* value 2379.91 was detected at Rabaa, while the lowest value (161) was found at Zaranik during summer. There was a graded increase in the average epiphytic chl *a* till its maximum at Rabaa. The data of Abd El-Karim *et al.* (2006) revealed that the epiphytic chl *a* at the inlet II were higher than the corresponding values inside the lake except at Rabaa. At the same time, the epiphytic chl *a* was much higher in the western basin than that of the eastern one.

5.2.2 Epipelic Algae

The qualitative study on the epipelic diatoms community that was carried out by Ehrlich (1975) revealed that a total of 147 taxa belonging to 45 genera were identified, of which 3 species and one variety were well described (Table 5.15). He concluded that the diversity of the diatom flora was much higher near the inlets than of the center of the lagoon; the decrease in the number of species is obviously related to the increase in salinity southwards. Ecologically, he classified the diatom species into 4 groups; the first group comprised 15 species and constituted about 20-40% of the total population, whereas towards the center of the lagoon their relative frequency increased and reach 100% at some places of the southern nearshore area. Because of their wide range of distribution within biotopes of various salinities, the diatoms of this group are termed as holoeuryhaline. The most common species of this group were *Mastogloia* spp., *Cocconeis bardawilensis*, *Amphora coffaeiformis Nitzschia sigma*, *N. frustulum* var. *subsalina*, *Rhopalodia gibberula* and *Gyrosigma scalporoides*. Group 2 composed of 30 species, occurred in many stations of the central and northern parts of the Lagoon, but was not found along the southern shores or at places f high salinities. The distribution of this group changed throughout the Lagoon, for instance; *Cocconeis scutellum* var. *parva* was abundant at the northern lagoon during January 1972, became more abundant at the central part of the lagoon during April 1974. Moreover, *Synedra tabulata* and *Licmophora remulus*, which were very rare during 1972 flourished abundantly in April 1974. *Nitzschia fusoides*, *N. granulata*, *N. panduriformis* var. *minor*, *Synedra tabulata*, *S. laevigata*, *Cocconeis scutellum* var *parva*, *Surirella fastuosa*, *S. striatula*, *Campylostylus striatus* and *Amphora* spp. were the most important members of group 2. Group 3 was composed of 80 species, which were found only at the Boughazes or parallel to the northern sand bar. The members of this group are also planktonic. It is quite possible that some of them have been transported into the lagoon by sea currents, which enter the inlets. *Coscinodiscus* spp., *Biddulphia aurita*, *Ttriceratium alternans*, *Thalassionema nitzschioides*, *Diploneis* spp., *Synedra crystallina*, *S. undulata*, *Mastogloia apiculata*, *M. angulata* and *Raphoneis superba* were common forms of this group. Group 4 was composed mainly of forms that are freshwater in

origin. These species were scarce and constituted a minor element of the diatom population. No living cells were found in the water of the lagoon. *Cyclotella ocellata*, *C. meneghiniana*, *Melosira granulata*, *Cymbella* sp. and *Gomphonema parvulum* were members of this group.

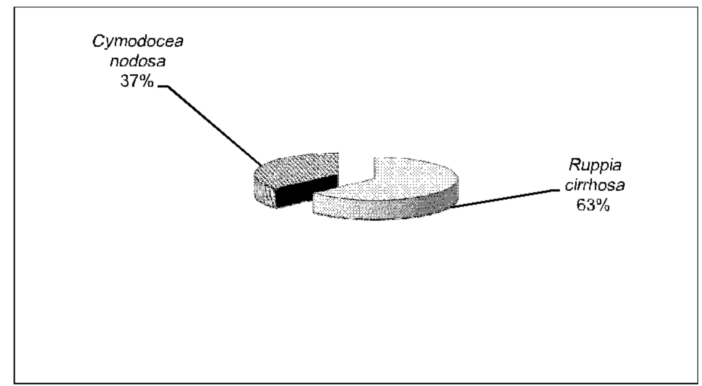


Fig. 5. 6. **Epiphytes distribution on two submerged sea grasses in Bardawil Lagoon**

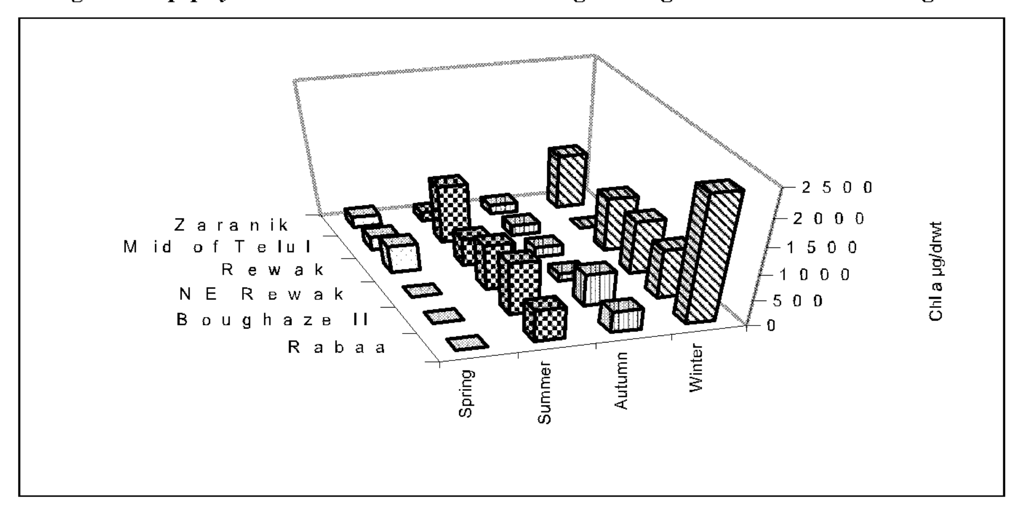


Fig. 5.7. **Epiphytic Chl *a* distribution at different stations in Bardawil Lagoon during 2004**

Abd El-Karim *et al.* (2006) studied the epipelic flora of the lagoon including the different algal groups. They identified 192 species belonging to 3 classes. Qualititively, diatoms were the most important group; 146 species representing 76.05% of all epipelic species. Cyanophytes ranked the second predominant position with relative occurrence of 21.35%, while dinophytes were very scarce; their relative occurrence was 2.6%. The number of diatom species recorded by both Ehrlich (1974) and Abd El-Karim *et al.* (2006) were close to each other; 147 and 146 respectively, but only 64 species were common and recorded by both. This means that 83 species replaced another group of 82

species during 30 years. Most of the fourth group reported by Ehrlich (1974) disappeared and a few of the first group.

Table 5.15. **Inventory of epipelic algae species recorded in Bardawil Lagoon during 1974 and 2006**

Bacillariophyceae	**Ehrlich (1974)**	**Abd El-Karim *et al.* (2006)**
Achnanthes taeniata **Grun.**		+
Achnanthes brevipes **Ag.**	+	
A. hauckiana **Grun.**	+	
A. hauckiana **var.** ***rostrata*** **Schultz**	+	
Actinocyclus ehrenbergii **Ralfs**	+	
Amphiprora alata **(Kutz.)**	+	+
Amphiprora paludosa **Smith**		+
Amphora coffaeiformis **Ag**	+	+
Amphora commutata **Grun**		+
Amphora crassa **Greg.**		+
Amphora dusenii **Brun**		+
Amphora descussata **Grun.**	+	
Amphora exigua **Grun.**	+	
Amphora granulata **Greg.**	+	
Amphora holsatica **Hust**	+	+
Amphora inariensis **Krammer**		+
Amphora kolbei **Aleem**	+	
Amphora lineolata **Ehren**		+
Amphora lybica **Ehren.**		+
Amphora ovalis **Kz.**		+
Amphora perpusilla **Grun.**		+
Amphora proteus **Greg.**	+	
Amphora **sp.**		+
Amphora strigosa **Hust.**	+	
Amphora subcapitata **(Kiss.) Hust.**		+
Amphora submontana **Hust.**		+
Assteromphalus flabellatus **(Breb.) Grev.**	+	
Azpeitia africana **(Jan. ex Sch.) Fry. & Wat.**		+
Azpeitia neocrenulata **(Vanland) Fry. & Wat.**		+
Bacillaria paxillifera **(Mull.) Hust.**		+
Biddulphia aurita **(Lyngb.) Breb.**	+	+
Biddulphia longicruris **Grev.**		+
Biddulphia mobiliensis **Bail.**	+	
Biddulphia reticulata **Roper**	+	+
Biddulphia rhombus **(Ehren.) Smith**	+	+
Campylodiscus bicostatus **Smith**		+
Campylodiscus daemilianus **Grun.**	+	

Bacillariophyceae	Ehrlich (1974)	Abd El-Karim *et al.* (2006)
Campylodiscus hibernicus **Ehren.**		+
Campylostylus striatus **Shad.**	+	+
Climacosphenia moniligera **Ehren.**		+
Cerataulus smithii **Ralf.**	+	
Cocconeis bardawilensis **nov. sp.**	+	+
Cocconeis calcar **(Cl.) Cl.**		+
Cocconeis dirupta **Greg.**		+
Cocconeis placentula **Ehren.**	+	+
Cocconeis scutellum **Ehren.**	+	+
Cocconeis scutellum **var.** ***parvum*** **Grun.**	+	
Cocconeis scutellum **var.** ***diminuta*** **Hust.**	+	
Cocconeis pseudomarginata **Greg.**	+	+
Cosinodiscus noricus **Cl.**		+
Cosinodiscus curvatulus **Grun.**	+	
Cosinodiscus excentricus **Ehren.**	+	
Cosinodiscus gigas **Ehren.**	+	
Cosinodiscus janischii **Schmidt**	+	
Cosinodiscus lineatus **Ehren.**	+	
Cosinodiscus nitidus **Greg.**	+	
Cosinodiscus radiatus **Ehren.**	+	
Cyclotella antiqua **Smith**		+
Cyclotella kuetzingiana **Thwait.**	+	
Cyclotella meneghiniana **Kutz.**	+	
Cyclotella ocellata **Pant.**	+	
Cyclotella striata **(Kz.) Grun.**		+
Cymbella affinis **Kz.**	+	+
Cymbella caespitosa **(Kz.) Brun.**		+
Cymbella microcephala **Grun.**	+	
Cymbella laevis **Nagel.**		+
Dimeregramma marinum **(Greg.) Ralf.**	+	
Diploneis fusca **(Gtreg.) Cl.**	+	
Diploneis interrupta **(Kz.) Cl.**	+	
Diploneis ovalis **(Hilse) Cl.**		+
Diploneis pseudovalis **Hust**	+	
Diploneis reichardii **Grun.**	+	
Diploneis weissflogii **(Schmidt) Cl.**	+	
Ditylum brightwellii **(West) Grun.**	+	
Epithemia turgida **(Ehren.) Grun.**	+	
Fragilariopsis cylindrus **(Grun.) Krieg.**		+
Fragilariopsis cylindriformis **Hasle**		+
Fragilaria pinnata **Ehren**	+	+
Fragilariopsis rhombica **(Meara) Hust**		+
Fragilariopsis curta **(Van Heurck) Hust**		+

Bacillariophyceae	**Ehrlich (1974)**	**Abd El-Karim *et al.* (2006)**
Fragilariopsis oceanica **(Cl) Hasle**		+
Fragilariopsis isabellae **Patrick**	+	+
Glyphonema parvulum **(Kutz.)**	+	+
Gomphonema parvulum **(Kz.) Grun.**	+	
Grammatophora angulosa **Ehren.**		
Grammatophora arcuata **Ehren.**	+	+
Grammatophora oceanica **(Ehren.) Grun.**	+	+
Gyrosigm acuminatum **((Kz) Cl**	+	+
Gyrosigma balticum **(Ehren.) Rabh.**	+	+
Gyrosigma exilis **Smith**		+
Gyrosigma eximium **(Thwa.) Bory**	+	+
Gyrosigma macrum **(Smith) Cl**		+
Gyrosigma obscurum **Ehren.**		+
Gyrosigma scalproides **(Rabh.) Cl.**	+	+
Gyrosigma spencerii **(Smith) Cl**		+
Gyrosigma speciosum **Lweis**		+
Gyrosigma strigilis **(Smith) Cl.**	+	
Gyrosigma temperii **Hust.**		+
Hantzschia amphioxys **(Ehren.)**	+	
Licmophora abbreviata **Ag.**	+	+
Licmophora ehrenbergii **(Kz.) Grun.**	+	
Licmophora flabellata **(Grun.) Ag.**	+	+
Licmophora gracilis **(Ehren.) Grun.**	+	+
Licmophora nubecula **(Kz.) Grun.**		+
Licmophora paradoxa **Smith & Heib.**		+
Licmophora remulus **Grun.**	+	+
Mastogloia angulata **Lewis**	+	+
Mastogloia apiculata **Smith**	+	+
Mastogloia braunii **Grun.**	+	+
Mastogloia corsicana **Grun.**	+	
Mastogloia crucicula **(Grun.) Cl.**	+	+
Mastogloia elliptica **(Thwat.) Grun.**	+	+
Mastogloia pumila **Grun.**	+	+
Mastogloia sirbonensis **nov. sp.**	+	
Mastogloia smithii **var.** ***heteroloculata*** **nov.**	+	+
Melosira granulata **(Ehren.) Ralf.**	+	
Melosira moniliformis **(Mull.) Ag.**	+	+
Melosira sol **(Ehren.) Kz.**	+	
Melosira sulcata **(Ehren.) Kz.**	+	+
Melosira rosaria		+
Navicula abrupta **Greg.**	+	
Navicula scutiformis **Grun.**		+
Navicula angustatula **Hust.**		+

Bacillariophyceae	Ehrlich (1974)	Abd El-Karim *et al.* (2006)
Navicula atomus Naeg.		+
Navicula cancellata Donk.	+	+
Navicula cincta (Ehren.) Kz.	+	+
Navicula distans Smith		+
Navicula detenta		+
Navicula directa Smith	+	+
Navicula epsilon Cl.	+	+
Navicula interruptestriata Simon.	+	
Navicula lanceolata (Ag.) Kz.		+
Navicula lyra Ehren.	+	+
Navicula mutica Kz.	+	+
Navicula mediterranea Cl.	+	
Navicula monilifera Cl.	+	
Navicula punctulata Smith	+	+
Navicula pupula var. mutata Kz.		+
Navicula palpebralis Breb.	+	
Navicula pusilla Smith		+
Navicula pseudomembranacea n. nom		+
Navicula ramosissima Ag.	+	
Navicula salinarum Grun.		+
Navicula scopularum Breb.	+	+
Navicula transitans Cl.		+
Navicula zosteretii Grun.	+	
Nitzschia acicularis W. Sm.		+
Nitzschia apiculata (Greg.) Grun.	+	
Nitzschia subacicularis Grun.		+
Nitzschia closterium Smith.		+
Nitzschia compressa Grun.		+
Nitzschia frustulum (Kz.) Grun.	+	+
Nitzscia filiformis (Smith) Hust.		+
Nitzscia fusoides nov. sp.	+	
Nitzscia granulata Grun.	+	+
Nitzschia inconspicua Cl.		+
Nitzschia liebetruthii Rabh. & Grun.	+	
Nitzschia leavis		+
Nitzschia lorenziana Grun.	+	
Nitzschia nana Ostr.		+
Nitzschia palea (Kz.) Smith		+
Nitzschia punctata (Smith) Grun.		+
Nitzschia sublinearis Hust		+
Nitzschia spathulata Breb.		+
Nitzschia spectabilis var. *americana* Grun.		+
Nitzschia dissipata (Kz.) Grun.		+

Bacillariophyceae	Ehrlich (1974)	Abd El-Karim *et al.* (2006)
Nitzschia obtusa **Smith**		+
Nitzschia ovalis **Arnott**		+
Nitzschia panduriformis **Greg.**	+	+
Nitzschia panduriformis **var. *minor* Grun.**	+	
Nitzschia sigma **Smith**	+	+
Nitzschia sigmoidea **(Ehren.) Smith**	+	+
Nitzschia subpunctata **Chol.**	+	+
Nitzschia tryblionella **Hant.**	+	+
Nitzschia vermicularis **(Kz.) Grun.**	+	+
Opephora marina **(Greg.) Petit.**		+
Pinnularia borealis **Ehren.**	+	
Plagiogramma vanheurckii **Grun.**	+	
Pleurosigma angulatum **(Quek.) Smith**	+	+
Pleurosigma directum **Ag.**		+
Pleurosigma elongatum **Smith**		+
Pleurosigma marinum **Donk.**		+
Pleurosigma normanii **Ralf.**		+
Pseudoeunotia doliolus **(Wall.) Grun.**	+	
Rhabdonema adriaticum **Kz.**	+	
Rhaphoneis superba **(Janisch) Grun.**	+	
Rhopalodia acuminata		+
Rhopalodia gibberula **(Ehren.) Mull.**	+	+
Stenopterobia arctica **Cl**		+
Stenopterobia delicatissima **Hust**		+
Stephanodiscus astraca **var. *minutula* (Kz.) Mull.**	+	
Striatella interrupta **(Ehren) Heib**		+
Striatella unipunctata **(Lyngb) Ag.**	+	+
Striatella fastuosa **Ehren.**	+	
Surirella brightwellii **Smith**		+
Surirella fastuosa **var *recedens* Ehren**	+	+
Surirella gemma **Ehren.**	+	
Surirella minuta **Breb**		+
Surirella intermedia **n. nom.**		+
Surirella robusta **Ehren**		+
Surirella spiralis **Tyrpin**	+	+
Surirella ovata **Kz.**	+	+
Synedra delicatula **Hust**		+
Synedra crystallina **(Ag.) Kz.**	+	
Synedra formosa **Hant**	+	
Synedra laevigata **Grun.**	+	
Synedra tabulata **(Ag.) Kz.**	+	
Synedra undulata **(Bailey) Greg**	+	
Tabillaria fenestrata **(Lyng) Kz**		+

Bacillariophyceae	Ehrlich (1974)	Abd El-Karim *et al.* (2006)
Tabillaria flocculosa **(Roth) Kz**		+
Thalassionema bacillare **(Heid. & Kolbe)**		+
Thalassionema frauenfeldii **Grun.**	+	+
Thalassionema javanicum **Van Heurck**		+
Thalassionema nitzschioides **(Grun.)**	+	+
Thalassiosira allenii **Takano**		+
Thalassiosira gracilis **Ehren.**		+
Trachyneis aspera **(Ehren.) Cl.**	+	
Triceratium alternans **Bail.**	+	+
Triceratium dubium **Bright.**	+	
Triceratium favus **Ehren.**	+	
Tropidoncis antarctica **Grun**		+
Tropidoneis lepidoptera **(Greg) Cl**	+	+
Tropidoneis elegans **(Smith) Cl**		
Cyanophyceae		
Aphanothece stagnina **(Sprengel) Boye-Pet**		+
Aphanothece salina **Gom.**		+
Aphanothece elabens **(Breb.) Elenk.**		+
Chroococcus giganteus **West**		+
Chroococcus limneticus **Lemm**		+
Chroococcus minutus **(Kz.) Nagel.**		+
Chroococcus turgidus **(Kz.) Nagel.**		+
Gloeocapsa magna **(Breb.) Holler.**		+
Gloeocapsa compacta **Kz**		+
Gloeocapsa crepidinum **Thuret**		+
Gloeocapsa dermochroa **Nagel.**		+
Gloeocapsa **sp.**		+
Gomphosphaeria compacta **(Lemm.) Strom**		+
Lyngbya salina **Kz.**		+
Lyngbya scottii **Frit.**		+
Lyngbya **sp.**		+
Microcoleus tenerrimus **Gom.**		+
Merismopedia elegans **Braun**		+
Merismopedia major **(Smith) Geit.**		+
Microcystis ichthyoblabe **Kz.**		+
Oscillatoria bonnemaissonii **(Crounan) Gom.**		+
Oscillatoria formosa **Bory**		+
Oscillatoria fragilis **Bocher**		+
Oscillatoria irrigua **(Kz.) Gom.**		+
Oscillatoria prolifica **(Grev.) Gom.**		+
Oscillatoria subcapitata **Ponom.**		+
Oscillatoria subbrevis **Schmidle**		+
Oscillatoria terebriformis **Agard**		+

Bacillariophyceae	Ehrlich (1974)	Abd El-Karim *et al.* (2006)
Oscillatoria margaritifera **(Kz.) Gom**		+
Oscillatoria boryana **(Agard) Bory**		+
Phormidium coutinhoi **Samp.**		+
Phormidium lucidum **(Agard.) Kz.**		+
Phormidium molle **(Kz.) Gom.**		+
Phormidium mucicola **Huber-Pest. et Naum**		+
Phormidium retzii **(Agard.) Gom.**		+
Phormidium **sp.**		+
Pseudanabaena crassa **Vozzh.**		+
Schizothrix funiculus **Geit.**		+
Spirulina major **Kz.**		+
Spirulina lapyrinthiformis **(Meneg.) Gom.**		+
Synechococcus aeruginosus **Nagel.**		
Dinophyceae		
Gymnodinium simplex **(Lohmann)Kofoid and Swezy**		+
Peridenium **sp.**		+
Prorocentrum compressum **(Baily) Abe ex Dodge**		+
Prorocentrum lima **(Ehren.) Dodge**		+
Prorocentrum michans **Ehren.**		+

Both the epipelic and epiphytic biodiversity (1.84 and 1.88, respectively) were very low when compared with the phytoplankton biodiversity (4.01). The biodiversity of the western basin (1.97) is the highest, when compared with both the inlets and the eastern basin (1.87 and 1.75, respectively). Both of the highest and lowest values of biodiversity (Table 5.16.) were randomly distributed among months. The maximum biodiversity of 3.07 was documented at El-Naser during May, while the minimum value of 0.26 was obtained at Inlet II during April. The highest regional value of 2.34 was reported at NW El-Rwoak, while the least regional value of 1.4 was measured at El-Telul.

Table 5.16. **Changes of epipelic species diversity in Bardawil Lagoon (Abd El-Karim *et al.* 2006)**

Stations	Jan.	Feb	Mar.	Apr	May	July	Aug.	Sep.	Oct.	Nov.	Average
El-Telul (I)	2.21	2.18	1.37	2.38	2.97	____	2.47	1.94	1.71	0.55	1.98
East El-Telul (II)	2.54	1.99	1.45	0.87	1.24	0.34	1.50	1.70	____	0.99	1.40
Zaranik (III)	1.91	1.89	____	1.48	1.98	1.29	1.56	1.92	____	1.65	1.71
Boughaze II (IV)	1.99	1.73	____	0.26	2.81	2.95	2.07	1.58	2.44	1.92	1.97
Mid El-Telul (V)	2.78	2.35	____	1.04	2.14	2.33	2.64	2.12	1.17	2.34	2.10
M Ebleas (VI)	1.17	1.33	2.38	2.01	1.79	0.69	2.40	1.04	1.51	1.49	1.58
Galss (VII)	2.10	2.38	1.79	1.90	1.89	1.63	2.08	0.75	2.07	0.85	1.74
Rowak (VIII)	2.05	2.22	1.10	1.82	1.90	2.93	1.72	1.38	0.54	2.33	1.80
NW Rowak (IX)	2.88	2.81	2.08	2.23	1.72	2.18	2.26	2.70	2.61	1.94	2.34
Boughaze I (X)	1.41	1.70	2.23	1.35	1.39	2.53	2.26	0.00	3.03	1.88	1.78
El-Nasr (XI)	2.98	2.62	2.07	2.21	3.07	1.91	2.45	1.41	0.00	1.96	2.07
Rabaa (XII)	2.38	2.48	1.59	0.69	2.26	1.65	2.23	1.67	0.00	1.87	1.68
Average	2.20	2.14	1.78	1.52	2.10	1.86	2.14	1.52	1.51	1.65	1.84

The highest total epipelic abundance (1491497.1 cells/cm^2) was found at El-Rwoak during November, while the least total epipelic abundance of 54.4 cells/cm^2 was obtained at Maskt Eblies during May (Figs. 5.8 and 5.9). The two basins are nearly similar, while the two inlets are very oligotrophic compared with the lagoon.

Cyanophytes were responsible for the patchy distribution of the total epipelic algae, but sometimes they completely disappeared. Blue-green algae ranked the first predominant position, with annual percentage abundance of 83.75% of the total annual standing crop. The highest cyanophytes density was1,477,058.6 cells/cm^2, with percentage abundance of more than 99%.

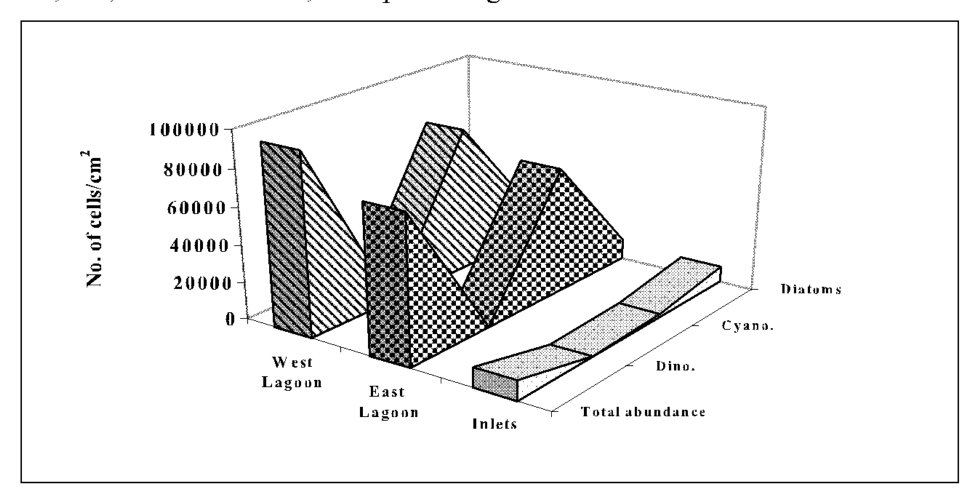


Fig.5.8. **Average of epipelic abundance of different groups at the main areas of the Lagoon during 2004 (Abd El-Karim *et al.* 2006).**

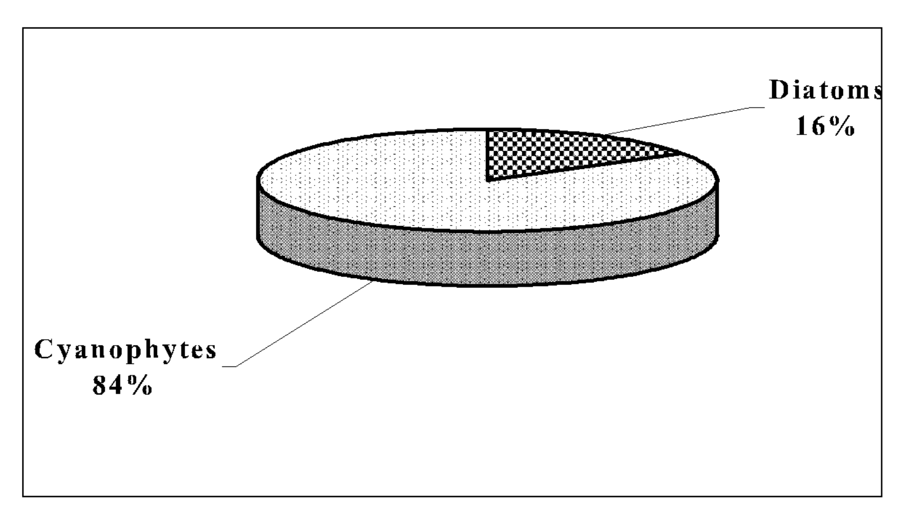


Fig. 5.9. **Annual percentage abundance of different epipelic groups during 2004 (Abd El- Karim *et al.* 2006)**

The average highest regional value (271,446.0 cells/cm^2) was detected at El-Rowak, while the least one (1091.9 cells/cm^2) was recorded at Inlet I. The data revealed that, cyanophytes abundance at the two Boughazes is very low compared with the proper lake (≈ 2% of the average abundance at the two basins), while the two basins are nearly similar.

Diatoms ranked the second predominant position, with annual percentage abundance of 6.0% of the total annual of epipelic algae. Diatoms were present at all stations, and the highest diatoms standing crop (75,827.6 cells/cm^2) was recorded at Zaranik during May, while the lowest abundance of 54.4 cells/cm^2 was found at Maskt Eblies during May. The data indicated that, the western basin is more eutrophic compared with the eastern one. On the other side, the Boughazes were more abundant with diatoms than with cyanophytes, but still lower than the lagoon.

5.3 SUMMARY

241 phytoplankton species were recorded in Bardawil Lagoon during the period from 1985 to 2002; diatoms were represented by 159 species, followed by dinoflagellates with 53 species. Cyanphytes, chlorophytes and chrysophytes were lesser recorded, and represented by 15, 8 and 4 species, respectively. Among the 241 recorded species, only 12 were common and documented in all investigations, while 56 ones are considered as new species that invaded the lagoon. The species belonging to Euglenophyceae and Chrysophyceae were sporadic, while the cryptomonodales were perennial species. It is noted that the species diversity of phytoplankton is high near the inlets compared with the center of the lagoon; this decrease is obviously related to the increase in salinity. During the period from 1969 till 2002, diatoms were the most comman group in Bardawil Lagoon. It constituted more than 60% of the total phytoplankton species and 30% of its density.

The majority of chlorophyll *a* values during the period from 1985 to 2002 were lower than 1 μg L^{-1}. These values indicate, to some extent, that Bardawil Lagoon is a very oligotrophic ecosystem.

The epiphytic algal species in Bardawil Lagoon of both plants *Cymodocea nodosa* (Ucria) Ascherson and *Ruppia cirrhosa* (Petagna) Grande, approximates 121 species belonging to 42 genera and 3 classes. Many of these species are known as attached species in both marine and fresh waters. 99 diatom species represent 77.9% of the total number of epiphytes species were recorded. The highest epiphytes standing crop of 23751.7 x 10^4/ g dry wt was reported during summer, while the lowest one (1553.8 x 10^4/ g dry wt) was found during autumn. The epiphytic algae are very rich in chlorophyll *a* compared with phytoplankton in Bardawil Lagoon. The highest chl *a* value 2379.9 μg/ gm dry wt was detected at Rabaa, while the lowest value (161 μg/ gm dry wt) was found at Zaranik during summer.

The qualitative study on the epipelic diatoms community of Lake Bardawil revealed that a total of 192 species belonging to 3 classes were identified. Qualititively, diatoms were the most important group; 146 species representing 76.1% of all epipelic species. Cyanophytes ranked the second predominant position with relative occurrence of 21.4 %, while dinophytes were very scarce; their relative occurrence was 2.6 %. The diversity of the diatom flora was much higher near the inlets than at the center of the lagoon; the decrease in the number of species is obviously related to the increase in salinity southwards.

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5.7. PLATES OF MICROALGAE: 5.1 – 5.16 (after Palmer 1980)

Plate 5.1.
Amphora lineolata
Amphora lybica
Amphora ovalis
Asterionella formosa
Biddulphia alternans
Biddulphia dubia

Plate 5.2.
Bacillaria paxillifera
Chaetoceros convolutus
Chaetoceros affinis
Climacosphenia moniligera
Coscinodiscus radiatus

Plate 5.3.
Cocconeis scutellum
Cocconeis placentula
Navicula protracta
Cymbella caespitosa
Cymbella affinis

Plate 5.4.
Fragilaria pinnata
Fragilaria oceanical
***Fragilaria* sp.**
Epithemia turgida
Epithemia sore

Plate 5.5
Gramatophora oceanica
Pleurosigma angulatum
Gyrosigma spencerii
Stenopterobia delicatissima
Navicula detenta

Plate 5.6
Hantzschia amphioxys
Haslea wawrikae
Leptocylidaricus danicus
Leptocylidaricus minimus
Licmophora gracilis
Licmophora flabellata

Plate 5.7
Mastogloia smethii
Mastogloia smethii
Melosira granulata
Melosira moniliformis
***Navicula* sp.**
Navicula lyra

Plate 5.8
Navicula pusilla
Navicula gracilis_
Nitzschia sublinearis
Nitzschia acicularis
Nitzschia inconspicua
Nitzschia palea

Plate 5.9
Nitzschia sigmoidea
Navicula lanceolata
Nitzschia sigma
Nitzschia punctata
Pseudonitzschia delicatissima
Pleurosigma elongatum

Plate 5.10
Rhopalodia acuminatum
***Rhopalodia gibba* (Girdle view)**
***Rhopalodia gibba* (Girdle view)**
Rhopalodia gibba
Skelatonema costatum
***Thalassiosira pacifica* (girdle view)**

Plate 5.11
Surirella ovata
Surirella capronii
Striatella unipunctata
Thalassionema frauenfeldii
Thalassiosira gracilis
Tabellaria flocculosa

Plate 5.12
Aphanothece stagnina
***Aphanothece* sp.**
***Aphanothece* sp.**
Chroococcus minutus
Chroococcus turgidus
Synechococcusdiatomicola

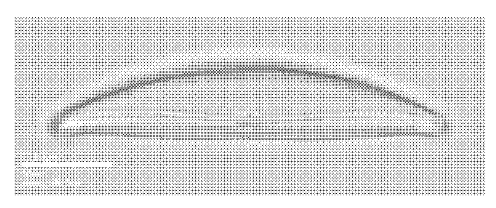
Plate 5.13
Gloeocapsa bituminosa
Gloeocapsa punctatata
Merismopedia major
Merismopedia elegans
Microcoleus tenerrimus
Oscillatoria princeps

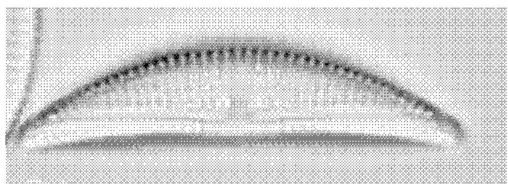
Plate 5.14
Oscillatoria formosa
Oscillatoria irrigua
Phormidium mucicola
Spirulina meneghiniana
Spirulina major

Plate 5.15
***Gymnodinium* sp.**
***Gymnodinium* sp.**
Peridinium cinctum
Peridinium cinctum

Plate 5.16
Dinophysis norvegica
Prorocentrum compressum
Prorocentrum emarginatum
Prorocentrum lima

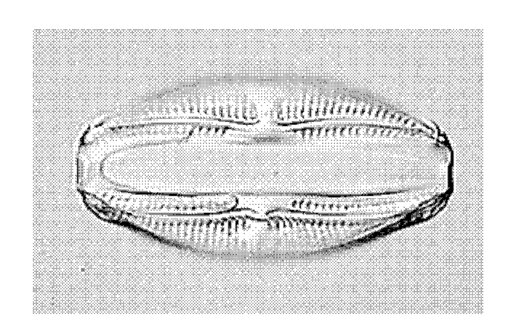
Plate 5.1



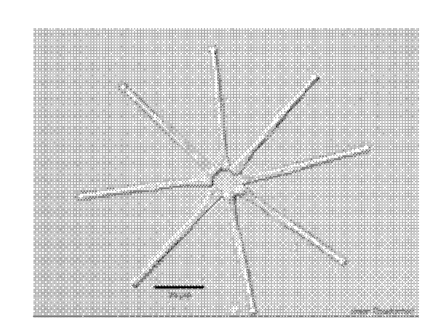


Amphora lineolata

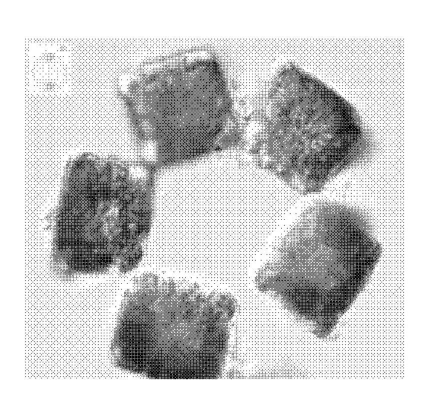
Amphora lybica



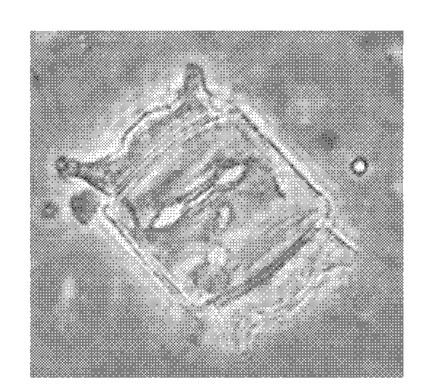
Amphora ovalis



Asterionella formosa

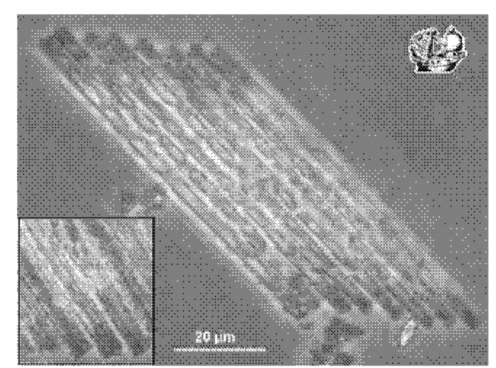


Biddulphia alternans

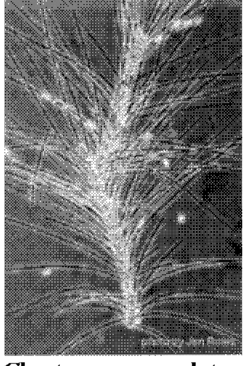


Biddulphia dubia

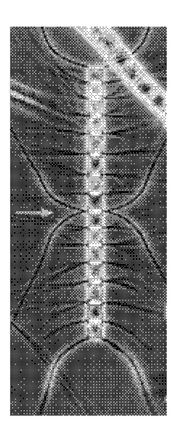
Plate 5.2



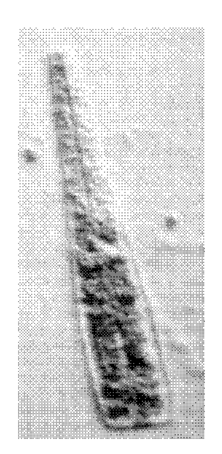
Bacillaria paxillifera



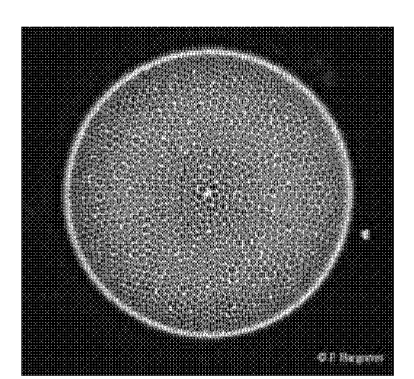
Chaetoceros convolutus



Chaetoceros affinis

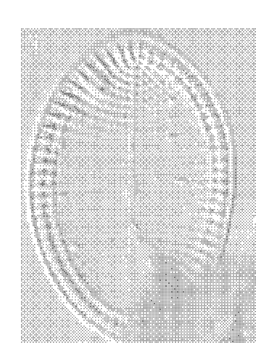


Climacosphenia moniligera

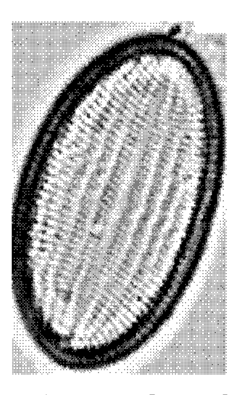


Coscinodiscus radiatus

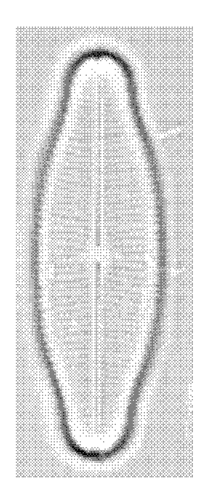
Plate 5.3



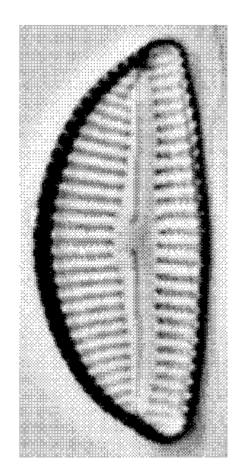
Cocconeis scutellum



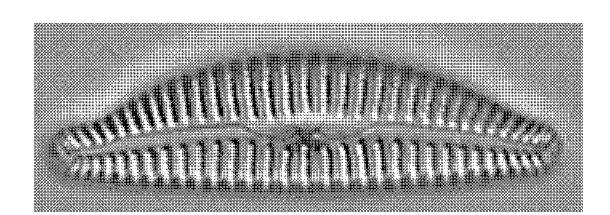
Cocconeis placentula



Navicula protracta

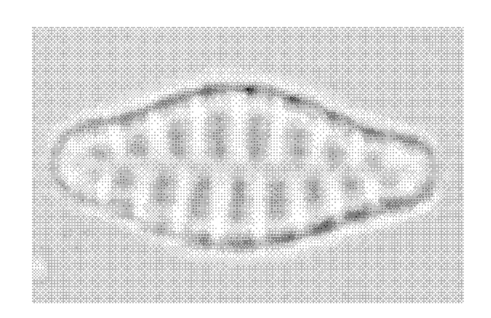


Cymbella caespitosa

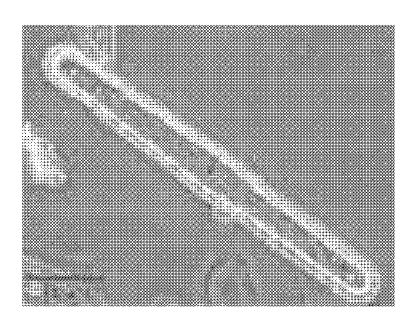


Cymbella affinis

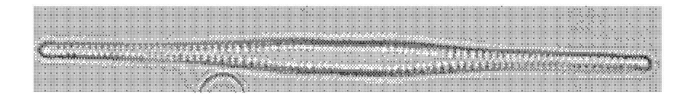
Plate 5.4



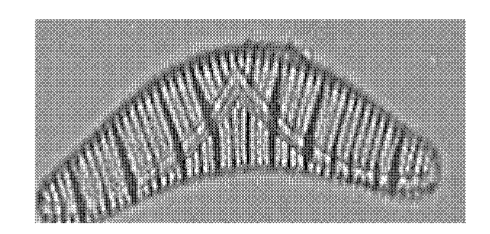
Fragilaria pinnata



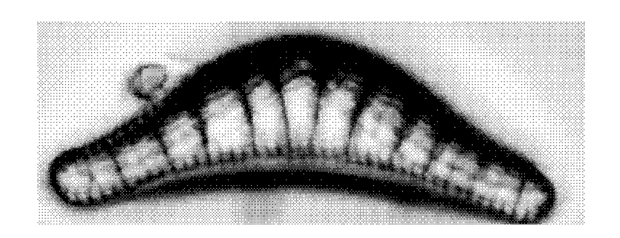
Fragilaria oceanica



Fragilaria sp.

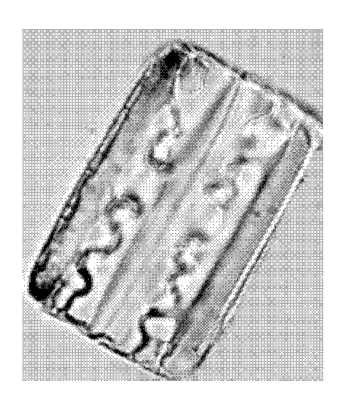


Epithemia turgida

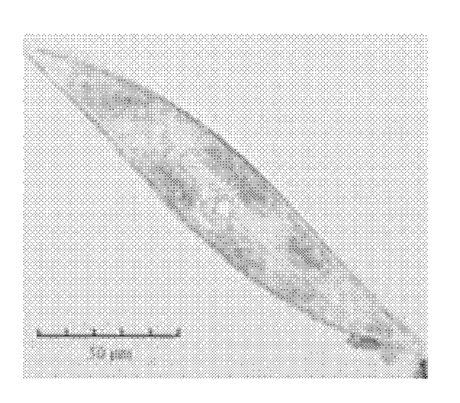


Epithemia sorex

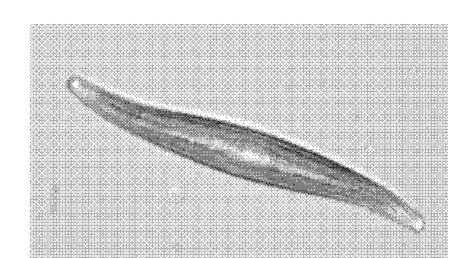
Plate 5.5



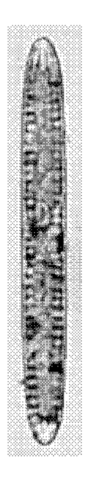
Gramatophora oceanica



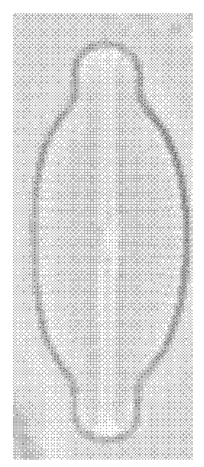
Pleurosigma angulatum



Gyrosigma spencerii

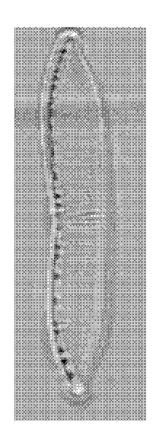


Stenopterobia delicatissima-

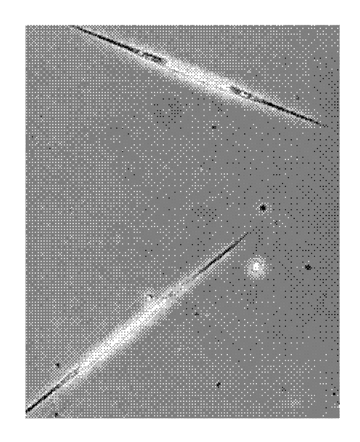


Navicula detenta

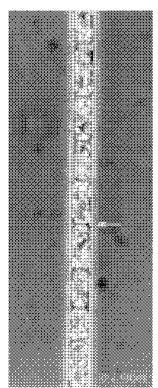
Plate 5.6



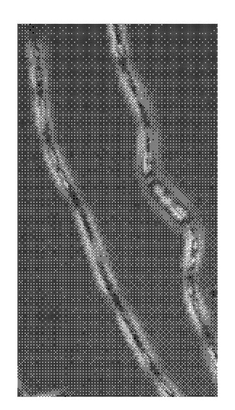
Hantzschia amphioxys



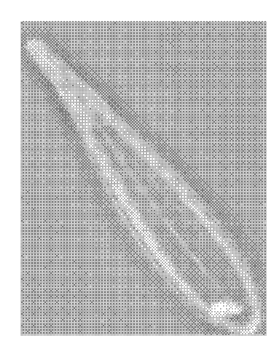
Haslea wawrikae



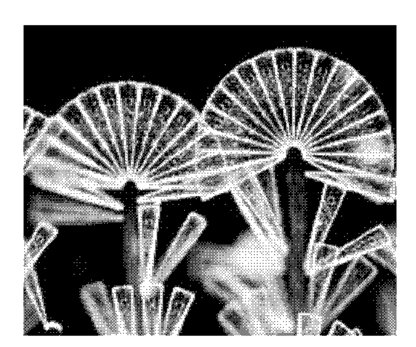
Leptocylidaricus danicus



Leptocylidaricus minimus

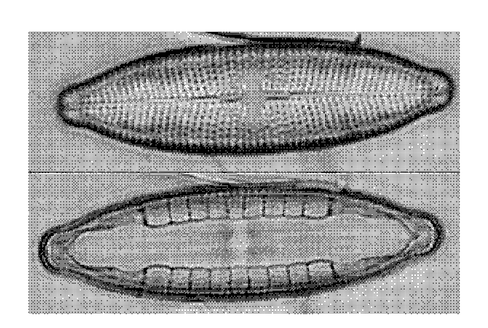


Licmophora gracilis

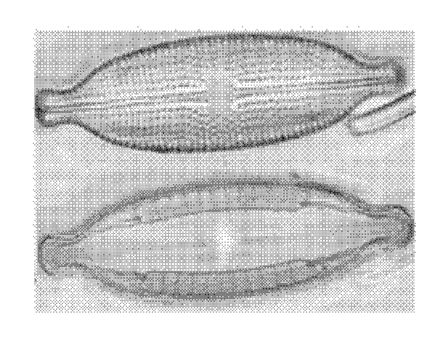


Licmophora flabellata

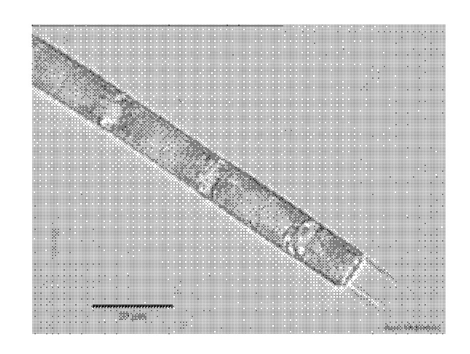
Plate 5.7



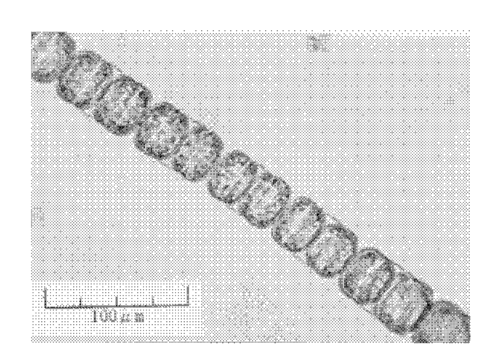
Mastogloia smethii



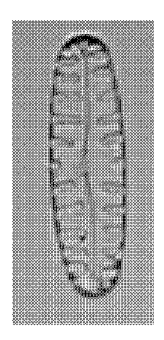
Mastogloia smethii var. *amphicephala*



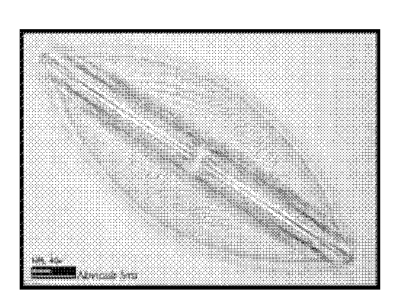
Melosira granulata



Melosira moniliformis

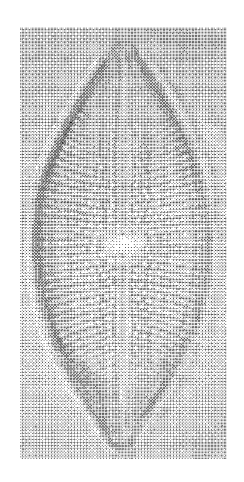


Navicula sp.

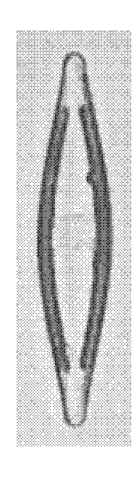


Navicula lyra

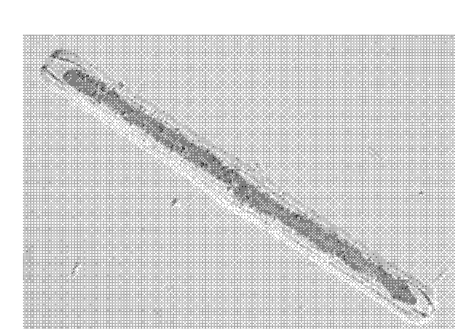
Plate 5.8



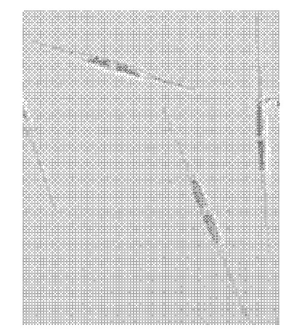
Navicula pusilla



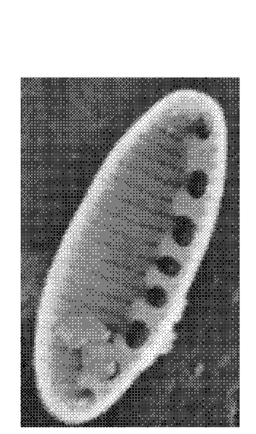
*Navicula gracilis_*



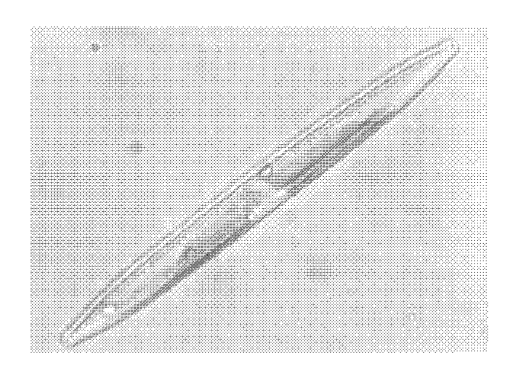
Nitzschia sublinearis



Nitzschia acicularis

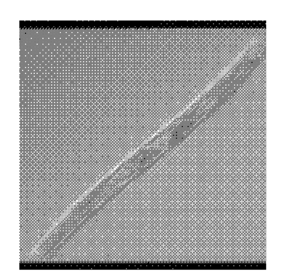


Nitzschia inconspicua

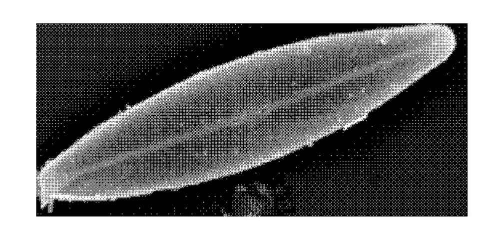


Nitzschia palea

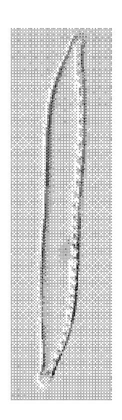
Plate 5.9



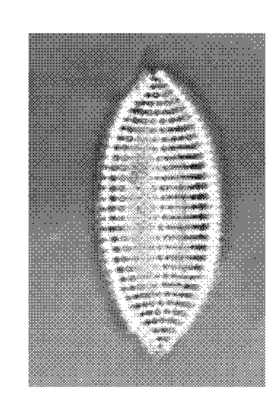
Nitzschia sigmoidea



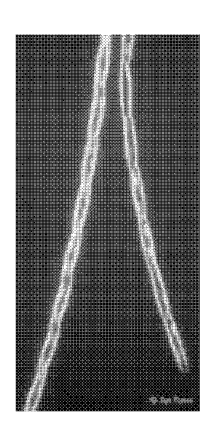
Navicula lanceolata



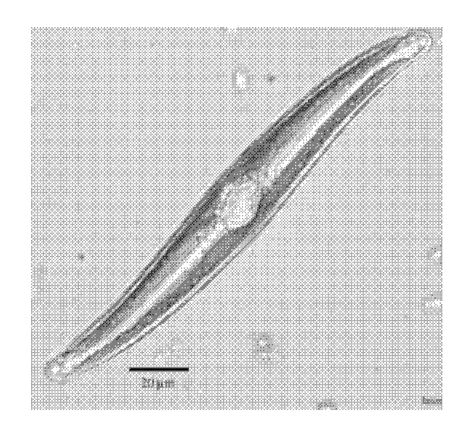
Nitzschia sigma



Nitzschia punctata

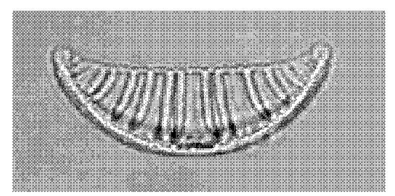


Pseudonitzschia delicatissima

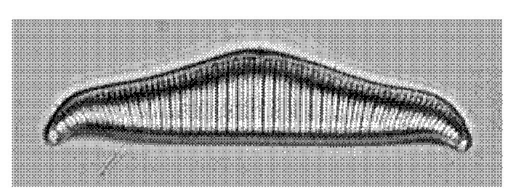


Pleurosigma elongatum

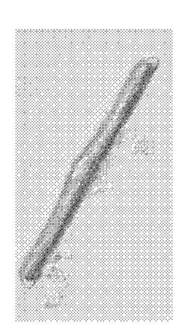
Plate 5.10



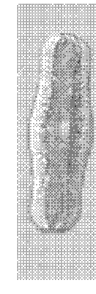
Rhopalodia acuminatum



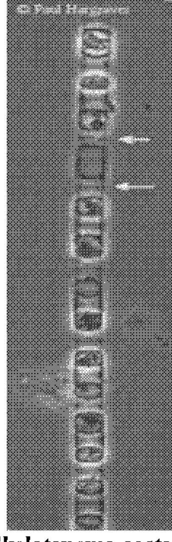
Rhopalodia gibba **(Girdle view)**



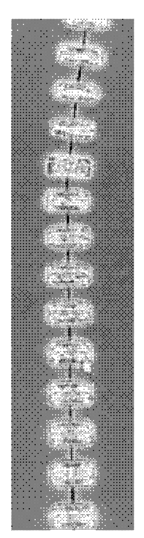
Rhopalodia gibba **(Girdle view)**



Rhopalodia gibba

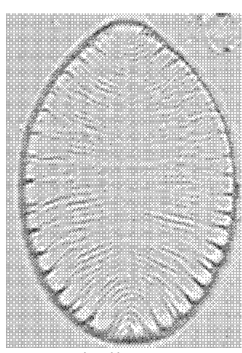


Skelatonema costatum

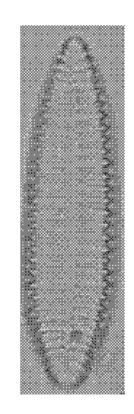


Thalassiosira pacifica **(girdle view)**

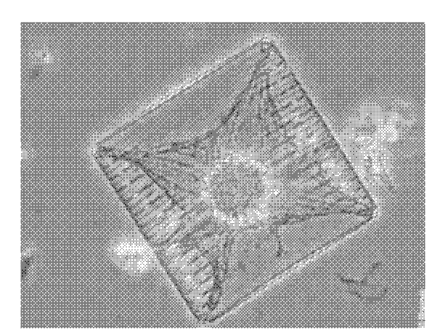
Plate 5.11



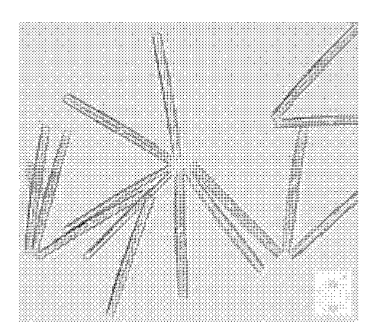
Surirella ovata



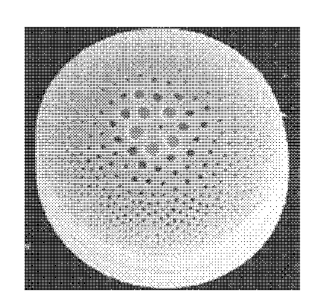
Surirella capronii



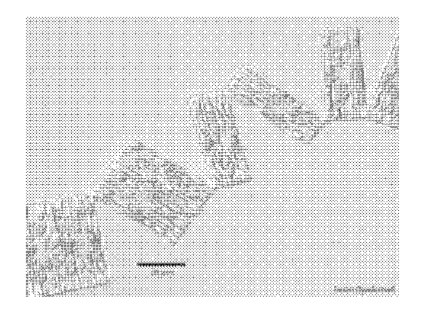
Striatella unipunctata



Thalassionema frauenfeldii

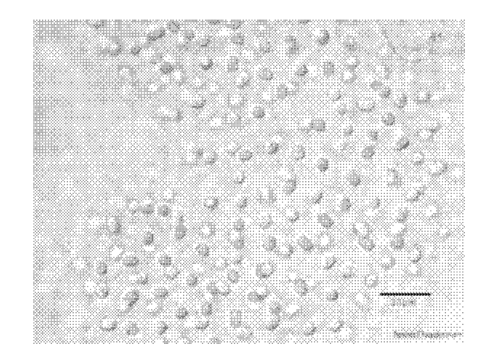


Thalassiosira gracilis

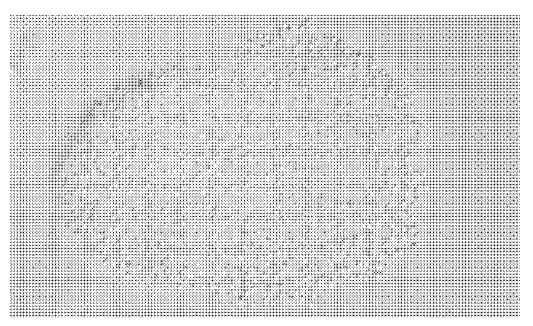


Tabellaria flocculosa

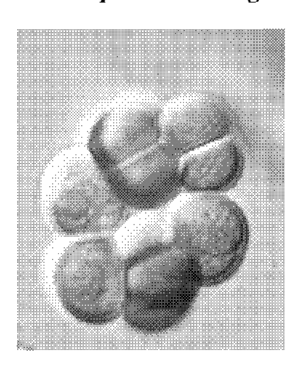
Plate 5.12



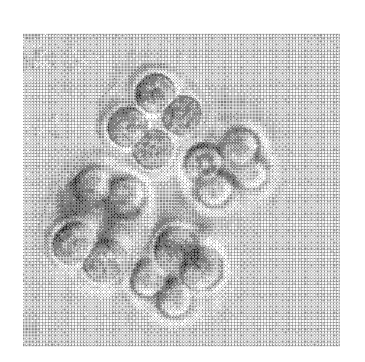
Aphanothece stagnina



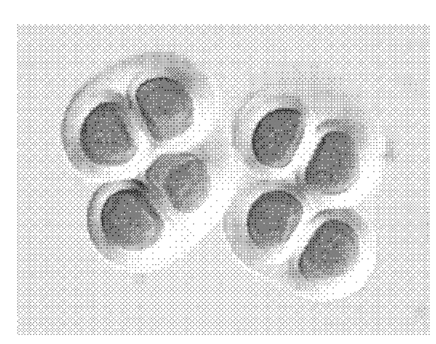
***Aphanothece* sp.**



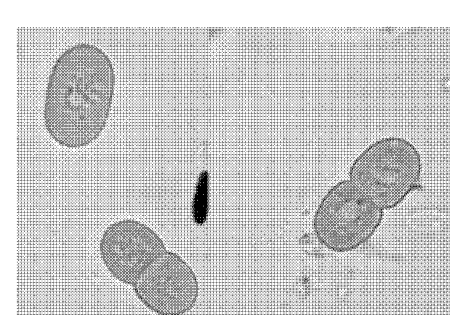
Chroococcus limneticus



Chroococcus minutus

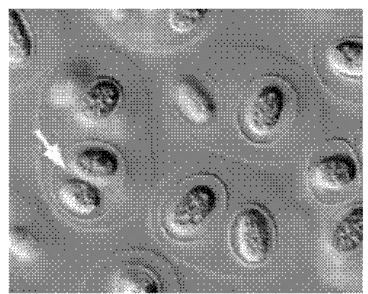


Chroococcus turgidus

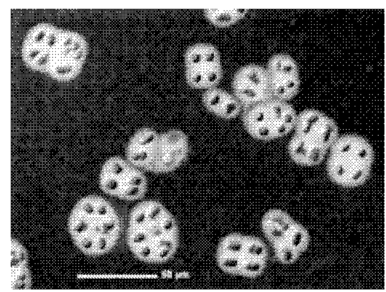


Synechococcus diatomicola

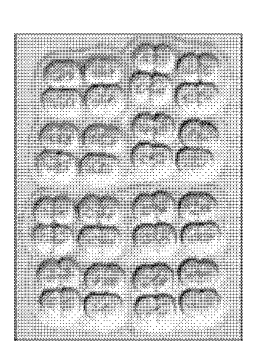
Plate 5.13



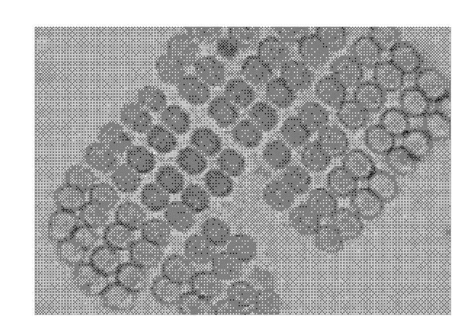
Gloeocapsa bituminosa



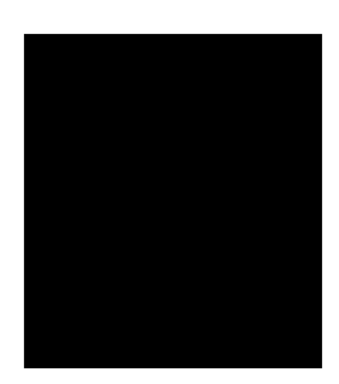
Gloeocapsa punctatata



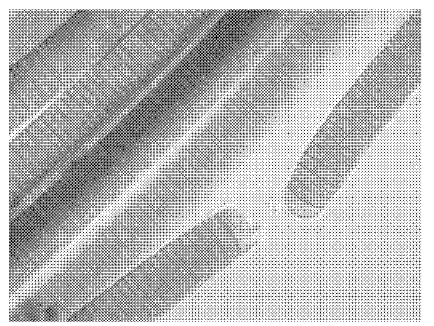
Merismopedia major



Merismopedia elegans

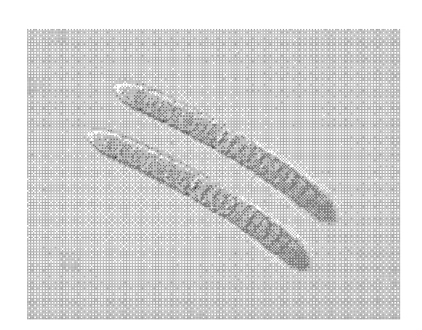


Microcoleus tenerrimus

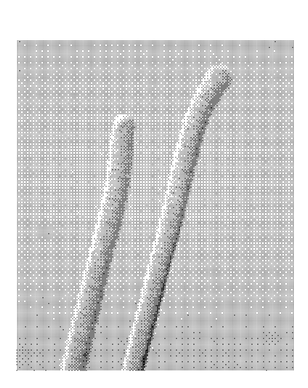


Oscillatoria princeps

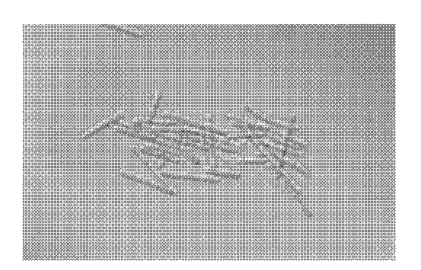
Plate 5.14



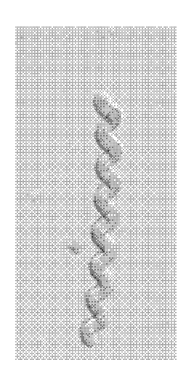
Oscillatoria formosa



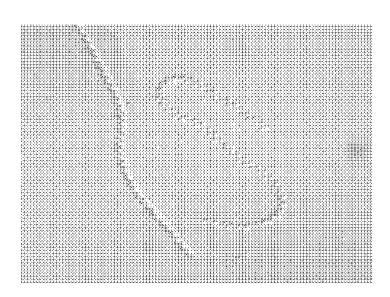
Oscillatoria irrigua



Phormidium mucicola

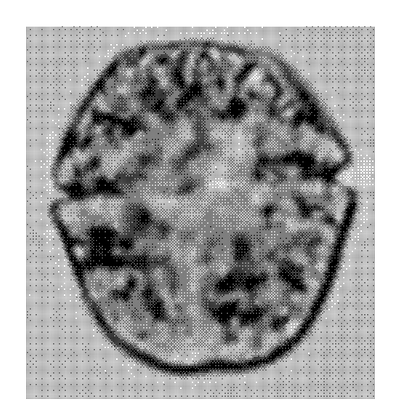


Spirulina meneghiniana

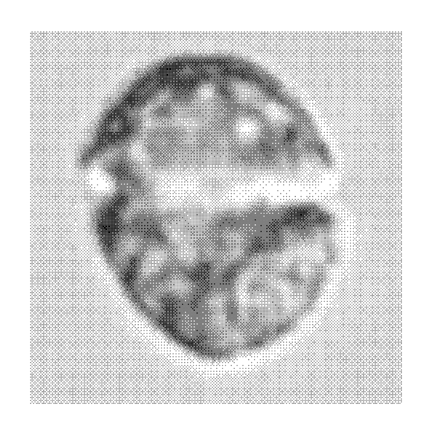


Spirulina major

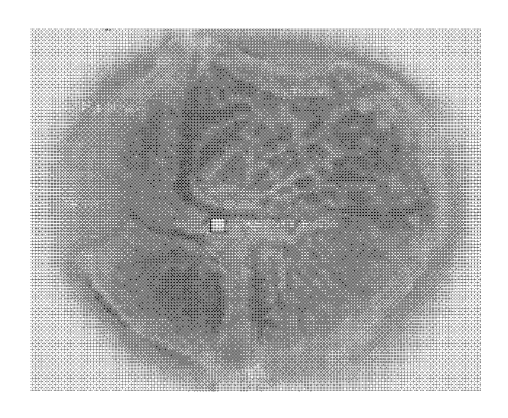
Plate 5.15



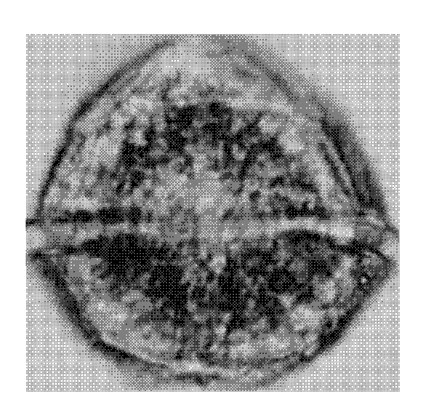
***Gymnodinium* sp.**



***Gymnodinium* sp.**

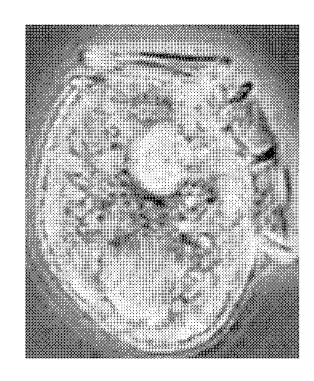


Peridinium cinctum

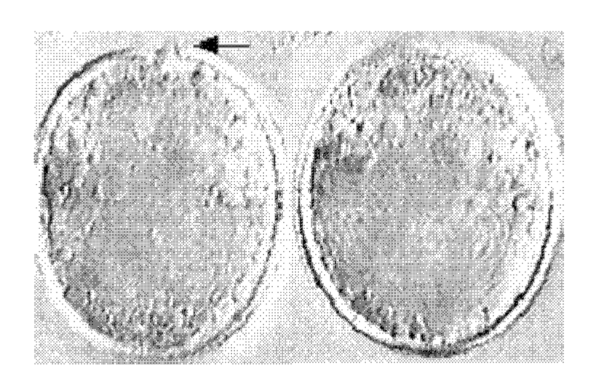


***Peridinium* sp.**

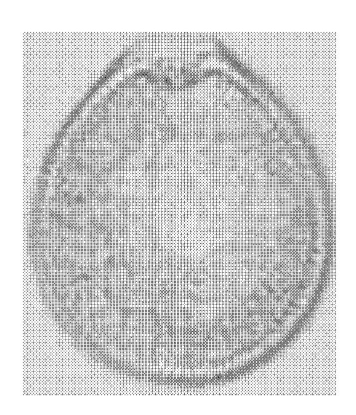
Plate 5.16



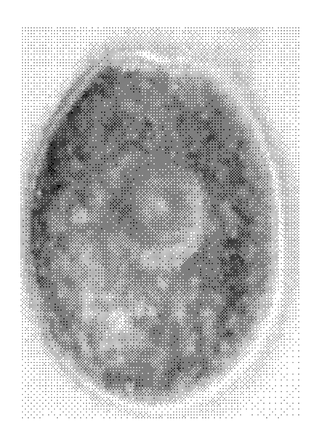
Dinophysis *norvegica*



Prorocentrum compressum



Prorocentrum emarginatum



Prorocentrum lima

Chapter 6
Bacteria and Actinomycetes

6.1 BACKGROUND

The majority of aquatic bacteria are motile, mainly by flagella, but some move by creeping along solid surfaces. Bacteria may live as plankton in water or grow on some solid substrates, such as detritus. Most bacteria are capable of living in either of these modes; but some can live only in one way. Bacteria living in the sea are different from those in fresh water; amongst the latter, those of the rivers are different from those of the saltwater lakes (Welch, as quoted by Shabana 1999).

Bacteria are often uniformly distributed at different depths, except in deeper layers, where the dissolved oxygen is greatly reduced or absent, thus affecting aerobic bacteria and providing favourable condition for anaerobic bacteria. In some lakes, the bacteria increase almost continuously from surface to bottom. In some other lakes, bacteria may be more numerous at the water surface than the bottom due to the accumulation of floating plankton at the surface (McDonough *et al.* 1986, Markosova *et al.* 1990). The quantity of bacteria tends to be greater and more varied in the areas of rooted aquatic vegetation (Quinn *et al.* 1985). Seasonal fluctuations of bacteria are different in different types of lakes. In a highly eutrophic lake, the plankton pulses that determine seasonal variations of bacteria, the activities of prophetic bacteria vary with the temperature. However this is more apparent in open water sites than in littoral sites (Lovell & Konopka 1985).

The bacterial community of marine waters comprises numerous species (Boyed 1974, Franklin *et al.* 1988). Although those species that grow in culture media have been well characterized, the degree to which they represent the entire community is unknown. The cultivable portion of open marine bacterial community is usually dominated by gram-negative bacteria, especially some genera such as *Pseudomonas* and *Vibrio.* Other genera commonly isolated from marine waters include *Photobacterium, Flavobacterium* and *Acinerobacter*, which make up a minor fraction compared with *Pseudomonas* and *Vibrio.* A large proportion of the cultivable bacteria isolated from the surface micro-layer is gram-positive. Since these bacteria tend to be more resistant to the effects of

solar radiation, *Staphylococcus* and *Micrococcus* species are commonly isolated from the surface micro-layer (these species may also inhabit the skin surface of vertebrates).

The bacterial flora of fresh water sediments is similar to that of marine and estuarine sediments and is dominated by the anaerobic bacteria. The proportion of gram-positive organisms increases with increasing the sediment depth, primarily due to the increasing abundance of *Clostridium* species in the anaerobic zones of sediments. *Bacillus* and other gram positive bacteria including coryno and filamentous forms are also abundant in aquatic environment (Tait 1981). In brackish water environment, saprophytic bacteria represent a small portion of the total bacterial count (Rheinheimer 1977). Saprophytic bacteria may represent a major part of the active bacterial flora at least in coastal areas. Isolation shows that most of the saprophytic bacteria are halophytic organisms adapted to the low salinity of brackish water.

6.2 VIABLE BACTERIAL COUNT

6.2.1 Total Viable Bacteria

The total viable aerobic heterotrophic bacterial count in the water of Lake Bardawil (in terms of colony forming units: cfu) varied between a minimum of 24 x 10^3 cfu ml^{-1} in April and a maximum of 569 x 10^3 cfu ml^{-1} in October. In sediments, it varied between 151 x 10^3 cfu g^{-1} in February and 6281 x 10^3 cfu g^{-1} in June (Fig. 6.1). The annual mean in water was 238 x 10^3 cfu ml^{-1}, compared with 2663 x 10^3 cfu g^{-1} in sediments (after Shabana 1999). Bacterial count in oligotrophic lakes ranged between 50 – 340 x 10^3 cfu ml^{-1}, while in mesotrophic lakes it varied between 450 – 1400 x 10^3 cfu ml^{-1} (Rheinheimer 1980). Accordingly , Lake Bardawil is considered as an oligotrophic lake. Heterotrophic bacteria have an important role in the reminiralization of the organic materials in aquatic ecosystems (Peduzzi *et al.* 1992). Decreasing of bacterial count during April in case of water and February in case of sediments may be due to the depletion of ammonia in the former, and the pregermination of seagrass *Ruppia cirrhosa* (old syn. *Ruppia spiralis*) in the latter. Due to this, O_2 liberated via roots and rhizomes was less than required for aerobic bacteria; this was confirmed by the ammonification and exoenzymatic bacterial activity that increased in sites dominated by the seagrass *Ruppia cirrhosa* compared with the bare sites (Shabana 1999).

The bacterial count in sites dominated by seagrass *Ruppia cirrhosa* was significantly higher than those in the bare sites. In general, benthic bacterial activity in Lake Bardawil is positively correlated with the seagrass production, due to the high input of organic matter by the seagrass (Shabana 1999). On a seasonal scale, bacteria and seagrass metabolism are inversely related, apparently because of competition for inorganic nutrients (Nancy *et al.* 1995 a).

Benthic bacteria is particularly active in seagrass dominated systems, as seagrasses provide, in addition to organic nutrients and carbon derived from

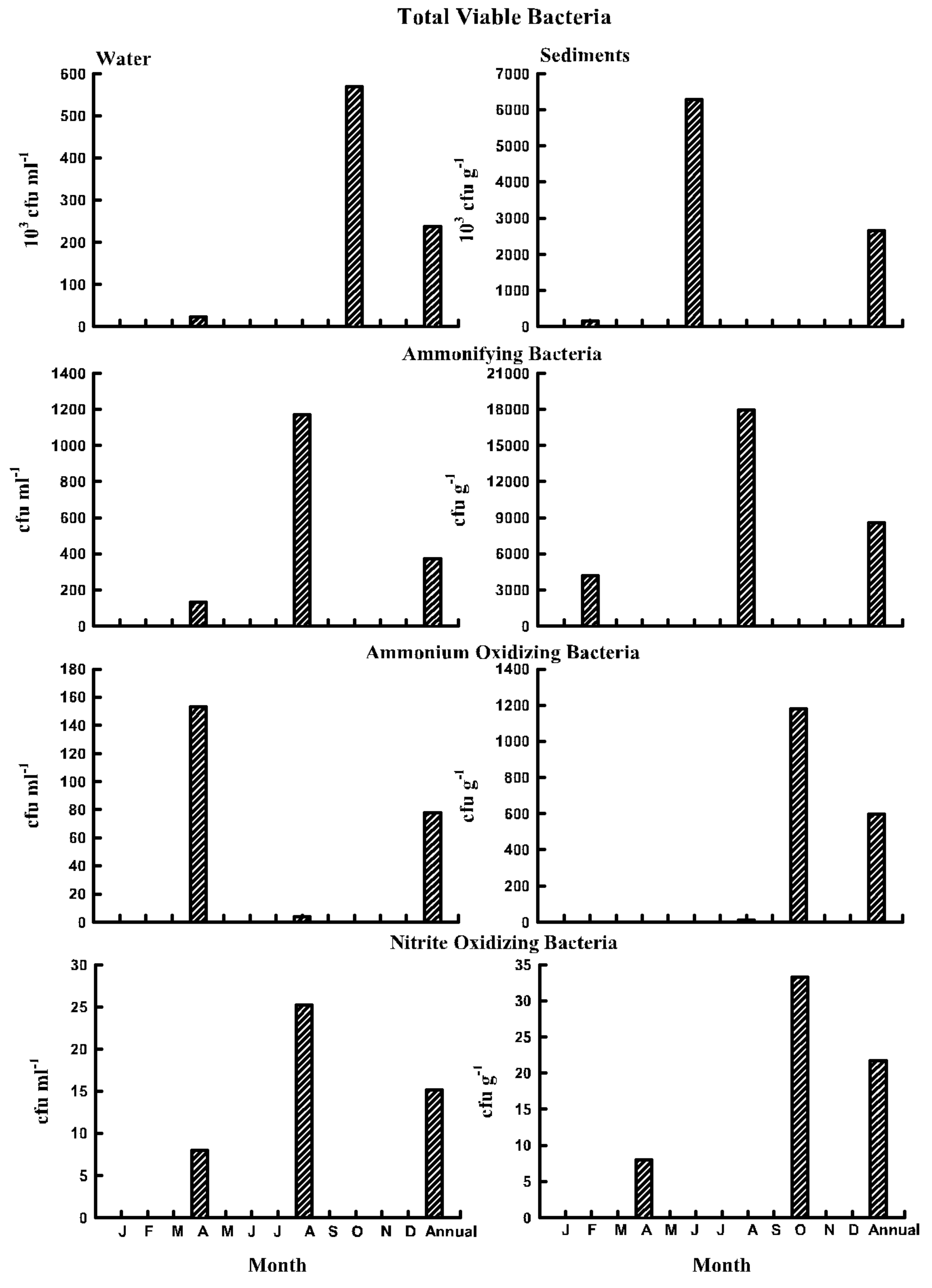


Fig. 6.1. Minimum, maximum and annual viable bacterial counts in Lake Bardawil.

plant detritus, labile organic compounds excreted by their roots and rhizomes (Jorgensen *et al.* 1981, Moriarty & Bon 1989, Moriarty *et al.* 1990, Chine-Leo & Benner 1991). Bacterial activity in seagrass sediments is influenced by the production of overlying macrophytes and the availability of additional nitrogen and phosphorus in the sediment that meet their nutritional requirements (Nancy *et al.* 1995 b).

6.2.2 Ammonifying Bacteria

The ammonifying bacterial count in water varied between a minimum of 131 cfu ml^{-1} in April and a maximum of 1171 cfu ml^{-1} in August; while in sediments it varied between 4207 cfu g^{-1} in February , and 17946 cfu g^{-1} in August. The annual average was 372 cfu ml^{-1} in water and 8581 cfu g^{-1} in sediments. The low ammonifying bacterial counts in April and February for water and sediments may be due to the low temperature during these months. On the other hand, the ammonifying bacterial counts increased in August due to the favourable temperature that was around the optimum (Shabana 1999). In addition, there was a highly significant difference in ammonifying bacterial count between the bare and seagrass dominated sites. Growth of submersed vascular plants can significantly affect nitrogen cycling in sediments.

6.2.3 Ammonium Oxidizing Bacteria

In water, the ammonium oxidizing bacterial counts in varied between a minimum of 4 cfu ml^{-1} in August and a maximum of 153 cfu ml^{-1} in April, with an annual average of 78 cfu ml^{-1}. There was no significant difference noted between the bare sites and seagrass dominated sites. In sediments, it varied between a minimum of 11 cfu g^{-1} in August and a maximum of 1180 cfu g^{-1} in October, with an annual average of 599 cfu g^{-1}. There was a highly significant difference between the bare sites and seagrass dominated sites.

6.2.4 Nitrite Oxidizing Bacteria

In general, nitrite oxidizing bacterial counts was lower than ammonifying bacterial counts in both water and sediments. The mean count in water varied between a minimum of 8.0 cfu ml^{-1} in April and a maximum of 25.2 cfu ml^{-1} in August; while in the sediment it varied between 8.0 cfu g^{-1} in April and 33.3 cfu in October. The annual average was 15.2 cfu ml^{-1} in the water and 21.7 cfu g^{-1} in the sediments.

6.3 IDENTIFICATION OF AEROBIC HETEROTROPHIC BACTERIA

The identification of aerobic heterotrophic bacteria by Shabana (1999) indicated that the predominant genera in water of Lake Bardawill were *Listeria, Bacillus, Corynebacterium, Streptococcus, Staphylococcus, Aeromonas, Vibrio, Pseudomonas, Pasteurella, Achromobacter, Moraxella, Branhamella* and *Neisseria*. (Table 6.1). The water was characterized by high presence of gram-negative isolates (about 78 %), catalase positive, oxidase positive and non-spore forming bacteria. Rhenheimer (1980) reported that the majority of marine

bacterial strains were gram-negative. Water of Lake Bardawil was distinct with the presence of genera *Pseudomoanas, Vibrio, Pasteurella, Achromobacter, Moraxella, Branhamella* and *Neisseria*. *Pseudomonas* was the most abundant genus in the water samples.

Table 6.1. **Distribution of aerobic heterotrophic bacterial species isolated from the water and sediments of Lake Bardawil (after Shabana 1999).**

Species	Water				Sediments			
	No. of isolates	Number of Sites			No. of isolates	Number of Sites		
		Vegetated	Bare	Total		Vegetated	Bare	Total
Aeromonas hydrophila	8	5	1	6	4	2	2	4
Bacillus sp.	4	1	1	2	30	6	1	7
Corynebacterium sp.	1	1	-	1	10	1	2	3
Listeria monocytogenes	10	2	2	4	5	1	1	2
Staphylococcus sp.	3	1	1	2	10	5	2	7
Streptococcus sp.	2	1	1	2	5	1	2	3
Achromobacter gr. VD	2	1	1	2				
Branhamella catarrhalis	7	4	-	4				
Moraxella sp.	1	-	1	1				
Neisseria sp.	7	1	2	3				
Pasteurella haemolytica	1	1	-	1				
Pasteurella multocida	1	-	1	1				
Pseudomonas aeruginosa	5	2	1	3				
Pseudomonas cepacia	10	3	2	5				
Pseudomonas luteola	11	3	3	6				
Pseudomonas maltophillia	1	1	-	1				
Pseudomonas oryzihabitans	1	1	-	1				
Pseudomonas putrefaciens	2	1	-	1				
Pseudomonas stutzeri	1	1	-	1				
Pseudomonas versicularis	9	4	1	5				
Vibrio damsela	3	1	1	2				
Vibrio fluvialis	2	1	1	2				
Aeromonas salmonicida					1	1	-	1
Agrobacterium radiobacter					6	5	-	5
Clostridium sp.					2	1	1	2
Erysipelothrix rhusiopathiae					2	-	2	2
Flavobacterium indologenes					1	1	-	1
Flavobacterium meningosept					1	1	-	1
Micrococcus sp.					37	5	2	7
Pseudomonas dimenuta					1	1	-	1
Pseudomonas fluorescens					1	1	-	1
Total species	22				15	15		

Sediments of Lake Bardawil were inhabited by genera not represented in water such as *Clostridium, Erysipelothrix, Agrobacterium, Micrococcus* and *Flavobacterium* (Table 6.1). The degree of dissimilarity between sediments and water is about 68% (based on Sørensen coefficient). Most gram-positive, non-motile, spore forming bacteria were observed in sediment samples. *Agrobacterium* was recorded only within sites dominated with seagrass *Ruppia*

cirrhosa. *Aeromonas*, *Pseudomonas*, *Bacillus* and *Clostridium*; as well as strains belonging to the *Coryneform* group, represent the major taxonomic groups of hererotrophic bacterial communities in the water-sediment interface with the study of Peduzzi *et al.* (1992), most bacterial isolates of sediments were gram-positive.

Strains belonging to *Bacillus*, *Corynobacterium*, *Streptococcus*, *Staphylococcus*, *Aeromonas* and *Pseudomonas* were present in both water and sediments. The most frequent species in water were *Pseudomonas luteola*, *Pseudomonas cepacia*, *Listeria monocytogenes*, *Pseudomanas versicularis*, *Aeromona*, *hydrophila*, *Branhamella catarrhalis* and *Neisseria* sp. *Pseudomonas* species (40 isolates) was the most frequent in the water, while *Micrococcus* (37 isolates), *Bacillus* (30 isolates), *Corynobacterium* (10 isolates), and *Staphylococcus* (10 isolates) were the most frequent in sediments (Table 6.1).

6.4 MICROBIAL ACTIVITY IN SEDIMENTS

6.4.1 Ammonification Activity

Nitrogen concentrations in sediments are controlled by microbial mediated transformation process such as the ammonification which is an energy releasing or exothermic reaction (breakdown of organic matter to ammonia). Ammonifying bacterial count and ammonification activity were found to correlate with each other. The most important steps in nitrogen cycle are the hydrolysis and degradation of particulate organic matter resulting in the liberation of ammonia (Fig. 6.2). Decomposition of protein, is initiated by the protein mineralization bacteria starting with hydrolysis of protein into simpler compounds and then into ammonia (NH_4) by the ammonifying bacteria (Jana 1994, Blackburn 1995).

6.4.2 Nitrification Activity

Nitrification is the process whereby ammonia (NH_4) is oxidized to nitrite (NO_2) and then to NO_3. The reaction is generally mediated in soil by the activities of two small groups of chemo-autotrophic bacteria. NH_4 oxidizers initiate the process with the formation of NO_2. In soil, five genera are able to oxidize NH_4 to NO_2 (*Nitrosomonas europa*, *Nitrosococcus nitrosus*, *Nitrosococcus oceanus and Nitrosococcus mobilis*; *Nitrosospira briensis*; *Nitrosolobus multiformis* and *Nitrosovibrio tenuis*). NO_2 oxidizers such as *Nitrobacter winoradskyi*, *Nitrospina gracilis* and *Nitrococcus mobilis* complete the process by converting NO_2 to NO_3 (Haynes 1986). Generally it can be said that, nitrification process may be related mainly to ammonium oxidizers then nitrite oxidizers. *Nitrobacter* appears to be the only genus of NO_2 oxidizers in soils even though NO_2 oxidation generally occurs as promptly as the NO_2 is formed (NO_2 rarely accumulates in nature; Haynes 1986).

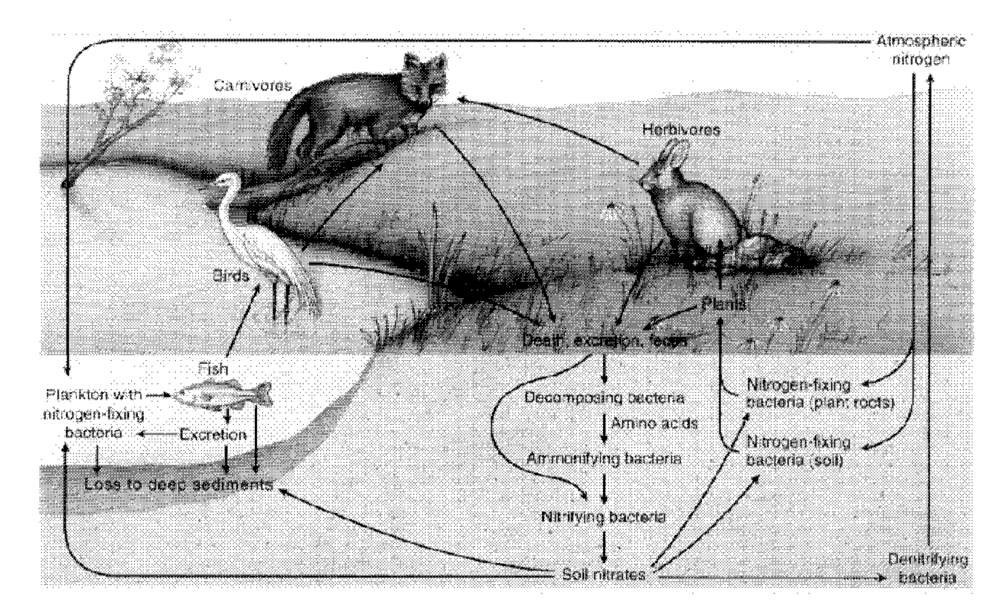


Fig. 6.2. **The nitrogen cycle: certain bacteria fix atmospheric nitrogen, converting it to a form that living organisms can use. Other bacteria decompose nitrogen-containing compounds from plant and animal materials, returning them to the atmosphere (after Raven *et al.* 2005).**

Nitrification activity in the sediments of Lake Bardawil reached a maximum of 4.3 µg-N-NO2 g^{-1} dry soil h^{-1} in October, while it was undetectable during August. This was confirmed by the increase of ammonifying bacterial count in Autumn and its decrease in Summer. pH is well known to be limiting factor for nitrification, the optimum pH for the growth and metabolism of autotrophic nitrifyers is in the range of 7 to 9. Toxic levels of NH_4 may result in inhibition of the activity of *Nitrobacter* and in the accumulation of NO_2 (Morrill & Dawson 1967). Reduction of ammonifying bacterial count and the drop of nitrification activity, in Lake Bardawil, during August may be related to the high temperature that exceeds the maximum level. Malhi & McGill (1982) found that the temperature optima of nitrifyer activity is 20 °C, but it almost ceased at 30 °C.

6.4.3 Role of the Seagrass *Ruppia cirrhosa* in Nitrification Process

Measuring ammonification, nitrification and exoenzymatic bacterial activity in sediment of Lake Bardawil demonstrated that *Ruppia cirrhosa* exerted a great effect on the nitrogen cycle by the decomposition of organic matter, direct uptake of NH_4 and NO_3, thereby reducing nutrient concentrations in water. Caffrey & Kemp (1991) demonstrated that rates of nitrification increased in vegetated sediment during July when plant biomass was high,

suggesting that plant oxidation of the rhizosphere was also an important mechanism controlling this process. Because aquatic macrophyte beds are common in many shallow water ecosystems, the activity of these plants could be regarded as an important factor controlling nitrogen pools and processes. Increased organic loading will increase NH_4 production (NH_4 supply to the sediment through ammonification activity) and O_2 consumption (decreasing O_2 concentrations and the depth of O_2 penetration). Nitrification may initially be enhanced by increasing NH_4 supply, but it decreases at high loading rates due to the reduction in O_2 supply (Caffrey *et al.* 1993).

6.4.4 Exoenzymatic Bacterial Activity

Exoenzymatic bacterial activity markedly changed in different seasons and along the trophic gradient. The mean exoenzymatic bacterial activity varied between a minimum of 0.4 μmol cm^{-3} min^{-1} in April and a maximum of 10.2 μmol cm^{-3} min^{-1} in August, with an annual mean of 0.7 μmol cm^{-3} min^{-1}. There was a higher significant difference between bare sites and seagrass dominated sites, this was confirmed by increase higher aerobic heterotrophic bacterial counts in seagrass beds than in bare sites. Exoenzymatic bacterial activity was found to be related to aerobic heterotrophic bacterial count, as they had minimum values in winter and maximum values in summer. Benthic bacterial activity tended to increase with increasing seagrass production (see Nancy *et al.* 1995a and b). In addition to the seasonality in bacterial activity imposed by temperature (Hall *et al.* 1989), seasonality in seagrass production is also expected to result in seasonality in bacterial activity. Similarly, differences in bacterial activity among sites may reflect differences in seagrass productivity. Thus, differences in seagrass production helped in explaining both seasonal changes in bacterial activity and differences among locations with different seagrass cover (Shabana 1999).

6.5 BACTERIAL BIOMASS

The cell volume of individual aquatic bacteria varied between a minimum of less than 0.005 and a maximum of more than 5 μm^3. The bacteria in a water sample, therefore, might differ in their volume in ratio of 1 : 10000 (Zimmermann 1977). Gocke *et al.* (2004) found that the volume of bacterial cells varied between 0.032 and 0.066 μm^3 in Santa Matra (Colombia), while Rabeh (2005) found that the volume of bacterial cells ranged between 0.156 and 0.427 μm^3 (with average of 0.258 μm^3) in Abu Za'bal wetland (Egypt). The foodweb in Lake Bardawil is mainly a detritus web, where the sea grasses are not utilized directly. Sea grasses produce huge amounts of plant debris which are decomposed by bacteria and fungi (Pisanty 1980). On the other hand, bacteria in aquatic food chain constitute a large biomass which is a continuous source of food for specialized bacteriovores (Wikner *et al.* 1990). Moreover,

bacteria and fungi convert dissolved organic matter derived from primary producers into an abundant biomass (Chin-Leo & Benner 1990).

The quantification of bacterial biomass in Lake Bardawil becomes particularly important in case of growth and production rate determinations. The study of Rabeh *et al.* (2006) in this Lake revealed that the seasonal averages of bacterioplankton biomass ranged between 6.2 mg m^{-3} in winter and 156.7 mg m^{-3} in summer (Fig. 6.3). Concerning spatial variation, bacterial biomass at the eastern sector ranged from 11.0 mg m^{-3} in winter to 113.4 mg m^{-3} in summer, with an annual average of 66.3 mg m^{-3}. On the other hand, the bacterial biomass varied at the western sector from 8.6 mg m^{-3} in winter to 62.7 mg m^{-3} in summer, with an annual average of 43.1 mg m^{-3}. At the first sea inlet (Boughaze I), bacterial biomass fluctuated between 14.7 mg m^{-3} in winter and 121.7 mg m^{-3} in summer, with an annual average of 78.6 mg m^{-3}. At Boughaze II, it ranged between 16.7 mg m^{-3} in winter and 305.0 mg m^{-3} in summer, with an annual average of 190.4 mg m^{-3}.

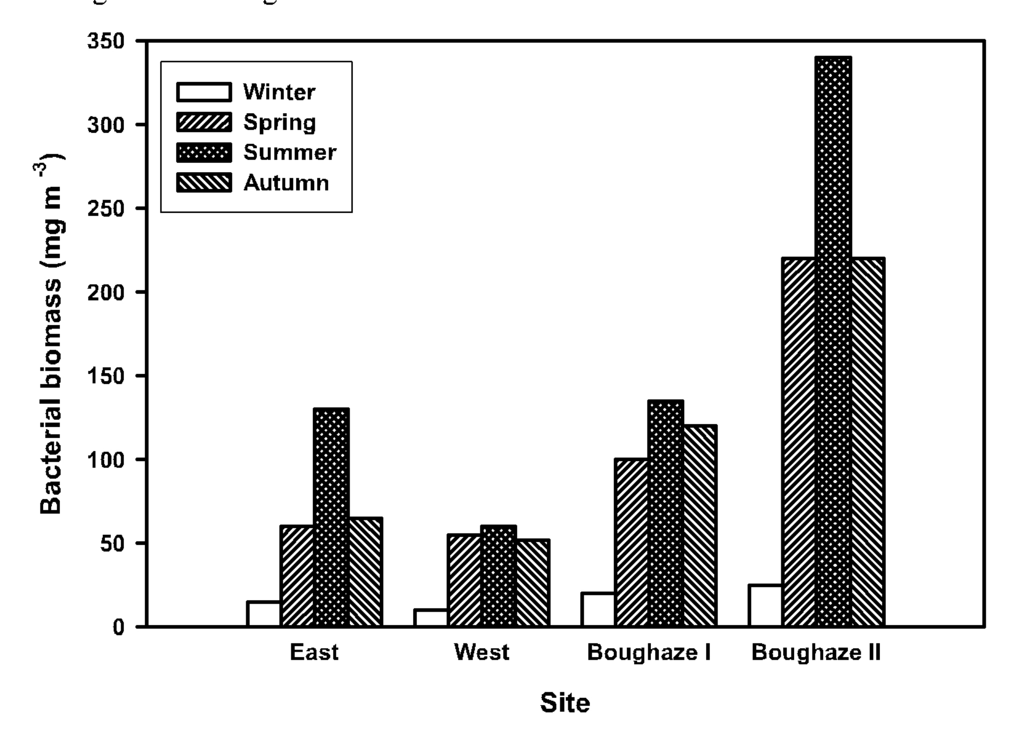


Fig. 6.3. **Seasonal variation in bacterial biomass in the water of Lake Bardawil (mg m^{-3}).**

Spatial and temporal variation in bacterioplankton biomass correlated significantly with the development cycles of phytoplankton and water temperature (r = 0.87). This finding was in agreement with those of Niewolak and Sinica (1981) for some fertilized polish lakes, and Rabeh (2005) for Abou

Za'bal wetland. Bacterial biomass is a much better criterion for the trophic value of water bodies than that of primary production, since the production of bacterial biomass increases with their fertility (Nagata 1988) and sometimes attains higher annual values than the production of phytoplankton (Simon *et al.* 1992).

6.6 INDICATORS OF FAECAL CONTAMINATION

Microbiological monitoring of water is carried out by detecting and enumerating groups of bacteria including total and faecal coliforms as well as faecal streptococci used as indicators of faecal contamination (Greenberg *et al.* 1992). The study of Rabeh *et al.* (2006) indicated that the number of total coliforms, faecal coliforms and faecal streptococci, as bacterial indicators in the eastern sector of Lake Bardawil, are more than the western sector (Fig. 6.4). This reflects the high load of bacterial pollution due to the activities of fishermen and their frequenting to the east, particularly near Telul fish marketing. In many cases, bacterial indicators are associated with disease-causing microorganisms of importance to public health (Godfree *et al.* 1997), as these pathogens can lead to water-borne related epidemic outbreaks (Morinigo *et al.* 1990, Martinez-Manzanares *et al.* 1991).

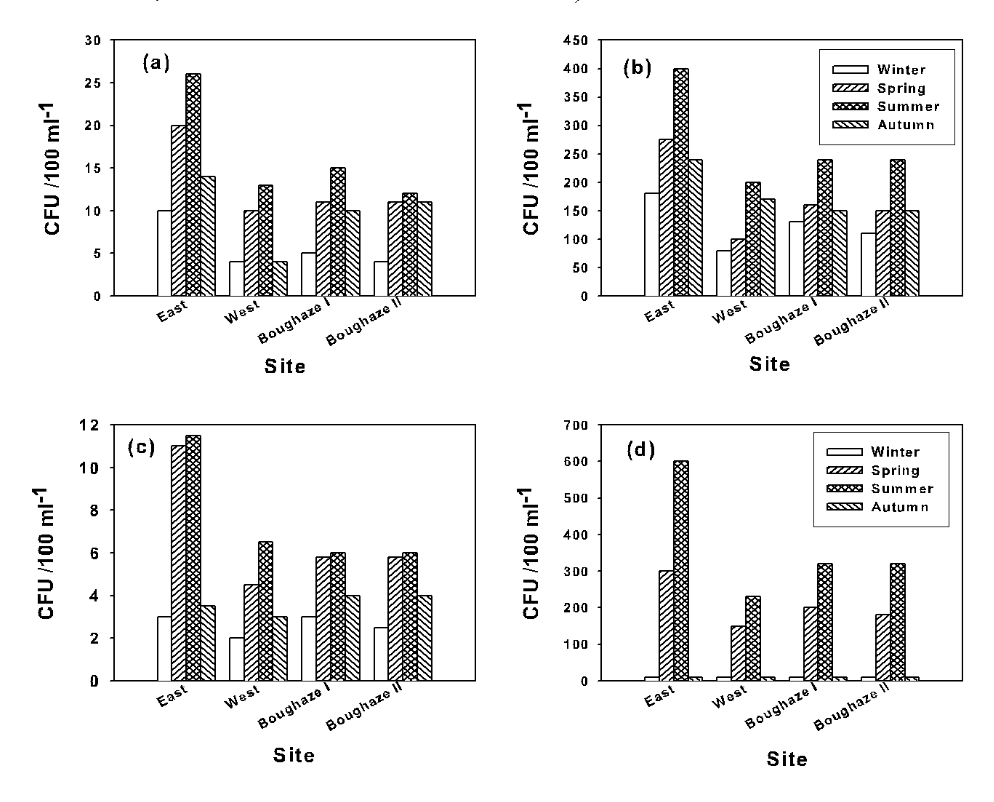


Fig. 6.4. **Seasonal variation in total coliforms (a), faecal coliforms (b), faecal streptococci (c) and *Edwardsiella* (d) in the water of Lake Bardawil.**

6.7 ACTINOMYCETES IN THE LAKE'S WATER

Rabeh *et al.* (2006) isolated 15 strains of actinomycetes from the water of Lake Bardawil, nine of them were identified as *Streptomyces*. Five isolates (three of them were *Streptomyces*) exhibited antagonistic activity against *E. coli* and *Edwardsiella* isolated from the water of this Lake. Seasonal average of actinomycetes counts indicated that summer records fluctuated more than the winter records. On the other hand, the western sector maintained the highest averages of actinomycetes compared with the eastern sector (Fig. 6.5). There is a negative correlation between the counts of actinomycetes on one hand, and the counts of faecal indicators and *Edwardsiella* on the other hand (r = -0.98 and -0.99, respectively). This inverse relationship may be due to the antibacterial activities of actinomycetes against these bacteria.

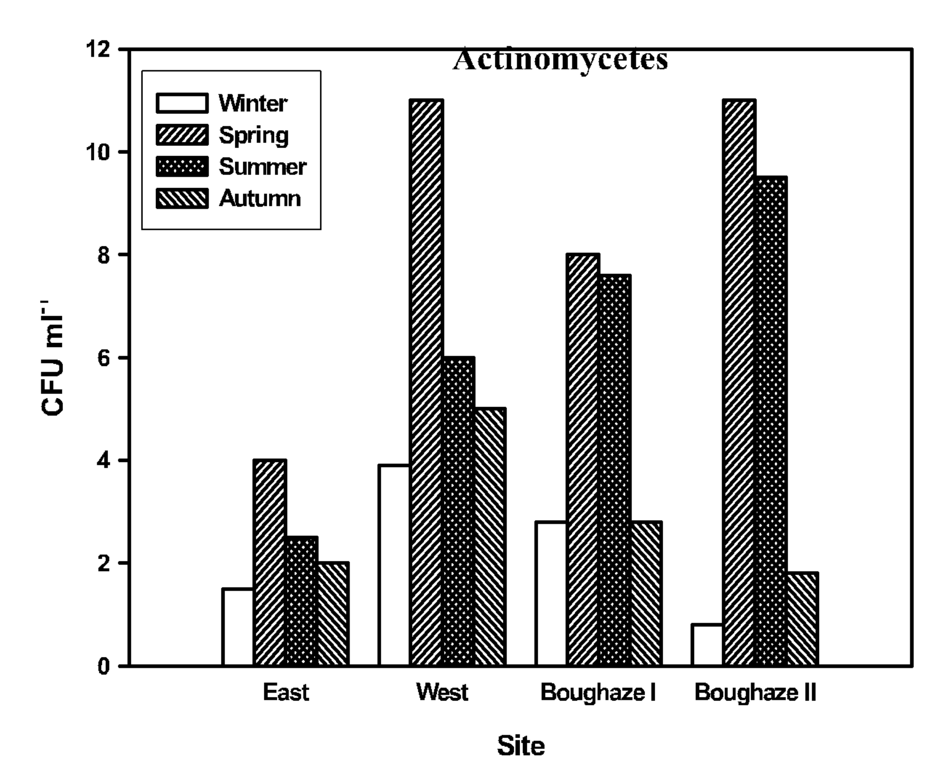


Fig. 6.5. **Seasonal variations in actinomycetes in the water of Lake Bardawil.**

6.8 SUMMARY

The majority of aquatic bacteria are motile, mainly by flagella, but some by creeping along solid surfaces. Bacteria may live as plankton in water or growing on some solid substrates, such as detritus.The total viable aerobic heterotrophic bacterial count in the water of Lake Bardawil (in terms of colony forming units: cfu) varied between a minimum of 24 x 10^3 cfu ml^{-1} in April and

a maximum of 569 x 10^3 cfu ml^{-1} in October. In sediments, it varied between 151 x 10^3 cfu g^{-1} in February and 6281 x 10^3 cfu g^{-1} in June. The annual mean in water was 238 x 10^3 cfu ml^{-1}, compared with 2663 x 10^3 cfu g^{-1} in sediments. The bacterial count in sites dominated by seagrass *Ruppia cirrhosa* was significantly higher than those in the bare sites. In general, benthic bacterial activity in Lake Bardawil is positively correlated with the seagrass production, due to the high input of organic matter by the seagrass

The ammonifying bacterial count in water varied between a minimum of 131 cfu ml^{-1} in April and a maximum of 1171 cfu ml^{-1} in August; while in sediments it varied between 4207 cfu g^{-1} in February, and 17946 cfu g^{-1} in August. The annual average was 372 cfu ml^{-1} in water and 8581 cfu g^{-1} in sediments. In water, the ammonium oxidizing bacterial count in water varied between a minimum of 4 cfu ml^{-1} in August and a maximum of 153 cfu ml^{-1} in April, with an annual average of 78 cfu ml^{-1}. In sediments, the ammonium oxidizing bacterial count varied between a minimum of 11 cfu g^{-1} in August and a maximum of 1180 cfu g^{-1} in October, with an annual average of 599 cfu g^{-1}.

In general, nitrite oxidizing bacterial count was lower than ammonifying bacterial count in both water and sediments. The mean count in water varied between a minimum of 8.0 cfu ml^{-1} in April and a maximum of 25.2 cfu ml^{-1} in August; while in the sediment it varied between 8.0 cfu g^{-1} in April and 33.3 cfu in October. The annual average was 15.2 cfu ml^{-1} in the water and 21.7 cfu g^{-1} in the sediments.

The identification of aerobic heterotrophic indicated that the predominant genera in water of Lake Bardawill were *Listeria, Bacillus, Corynebacterium, Streptococcus, Staphylococcus, Aeromonas, Vibrio, Pseudomonas, Pasteurella, Achromobacter, Moraxella, Branhamella* and *Neisseria*. Sediments of Lake Bardawil were inhabited with genera not represented in water such as *Clostridium, Erysipelothrix, Agrobacterium, Micrococcus* and *Flavobacterium*

Nitrification activity in the sediments of Lake Bardawil reached a maximum of 4.3 µg-N-NO2 g^{-1} dry soil h^{-1} in October, while it was undetectable during August. This was confirmed by the increase of ammonifying bacterial count in Autumn and its decrease in Summer. Measuring ammonification, nitrification and exoenzymatic bacterial activity in sediment of Lake Bardawil demonstrated that *Ruppia cirrhosa* exerted a great effect on the nitrogen cycle by the decomposition of organic matter, direct uptake of NH_4 and NO_3, thereby reducing nutrient concentrations in water.

The mean exoenzymatic bacterial activity varied between a minimum of 0.4 µmol cm^{-3} min^{-1} in April and a maximum of 10.2 µmol cm^{-3} min^{-1} in August, with an annual mean of 0.7 µmol cm^{-3} min^{-1}. There was a higher significant difference between bare sites and seagrass dominated sites, this was

confirmed by the higher increase of aerobic heterotrophic bacterial counts in seagrass beds than in bare sites.

The seasonal averages of bacterioplankton biomass were ranged between 6.2 mg m^{-3} in winter and 156.7 mg m^{-3} in summer. Spatial and temporal variation in bacterioplankton biomass correlated significantly with the development cycles of phytoplankton and water temperature ($r = 0.87$).

The number of total coliforms, faecal coliforms and faecal streptococci, as bacterial indicators in the eastern sector of Lake Bardawil, are more than the western sector. This reflects the high load of bacterial pollution due to the activities of fishermen and their frequentation to the east, particularly near Telul fish marketing.

Edwardsiellosis caused by *Edwardsiella tarda*, is a subacute to chronic disease for variety of fish species. On the other hand, *Edwardsiella tarda* can pose a health threat to humans, usually manifesting itself as gastroenteritis and diarrhea; however, extraintestinal infections can produce a typhoid-like illness, meningitis, peritonitis with sepsis, cellulites, and hepatic abscess. The eastern sector of Lake Bardawil attained also the highest numbers of *Edwardsiella tarda* (11 cfu 100 ml^{-1} in winter and 615 cfu 100 ml^{-1} in summer), while the western sector attained the lowest (7 cfu 100 ml^{-1} in winter and 220 cfu 100 ml^{-1} in summer).

Fifteen strains of actinomycetes from the water of Lake Bardawil, nine of them were identified as *Streptomyces*. Five isolates (three of them were *Streptomyces*) exhibited antagonistic activity against *E. coli* and *Edwardsiella* isolated from the water of this Lake. Seasonal average of actinomycetes counts indicated that summer records fluctuated more than the winter records. On the other hand, the western sector maintained the highest averages of actinomycetes compared with the eastern sector.

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Chapter 7
Zooplankton

Lagoons are among the most productive aquatic ecosystems, which for thousands of years have been exploited by man (Lasserre 1979). Bardawil Lagoon is a shallow natural depression; 1 – 3 m below mean sea level, separated from the Mediterranean Sea by a narrow arc-shaped sedimentary bar of about 100 km length, with a maximum width of 2 km. Bardawil Lagoon, particularly at Zaranik area (the eastern region) has been described as a wetland of a major international importance for migrating water birds passing through the eastern Mediterranean region, where wetlands are scarce (Meininger & Atta 1990, Varty *et al.* 1990). The Lagoon is considered a main ecological and economic natural resource of North Sinai region. A recent estimate of fish and crustaceans production amounts to 2801 ton (GAFRD 2004), composed of 35.8 % mullets, 21.2 % shrimps, 18.6 % crabs, 8 % sea bream, 5.1 sole, 2.4 % sea bass and 9.4 % miscellaneous,.

The characteristics of catch composition in Bardawil Lagoon have greatly changed since 1995, when the contribution of the species with most economic value (sea bream and sea bass) dropped sharply. On the contrary, other species as crabs and shrimps have attained a noticeable contribution to the catch (El – Ganainy *et al.* 2002). The study of zooplankton communities seems to be useful for the evaluation of the Lagoon ecology and contributes a solid base for its management.

Several studies have been carried out on the abundance, distribution and biomass estimation of zooplankton in the Mediterranean Sea (El-Maghraby 1964, Dowidar & El-Maghraby 1970 & 1973, Hussein 1977 & 1997, El-Zawawy 1980, Dowidar 1981, Nour El-Din 1987, Aboul-Ezz *et al.* 1990, Abdel Aziz 1997, Hussien & Abdel Aziz 1997 , Abdel Aziz & Dorgham 2002), despite the importance of zooplankton in Lagoon food chain, little is known about the distribution and standing crop of zooplankton of Bardawil Lagoon. Kimor (1975) carried out a preliminary study on the plankton of Bardawil hyper

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saline Lagoon. Ibrahim *et al.* (1987) included zooplankton in their studies on fishery and management of the Lagoon. Fouda *et al.* (1985) listed 87 zooplankton species in Bardawil Lagoon and mentioned that some species occur over a relatively wide range of habitats, while others were confined to certain localities. They added that zooplankton populations were poor in variety of species, compared to phytoplankton.

7.1 PRESENT STATUS OF ZOOPLANKTON

El- Shabrawy (2006) studied the zooplankton community structure during 2002/2003, and he selected 12 stations to represent different habitats of the Lake (Fig. 7.1, Table 7.1). A total of 58 zooplankton species were recorded; copepods were the most abundant species, contributing about 69.9 % of total zooplankton density. Zooplankton reached the highest density at station X during summer (198,500 ind. m^{-3}). Protists (23 species), made up 10.3 % of total zooplankton. Winter was characterized by the highest standing crop (Table 7.2).

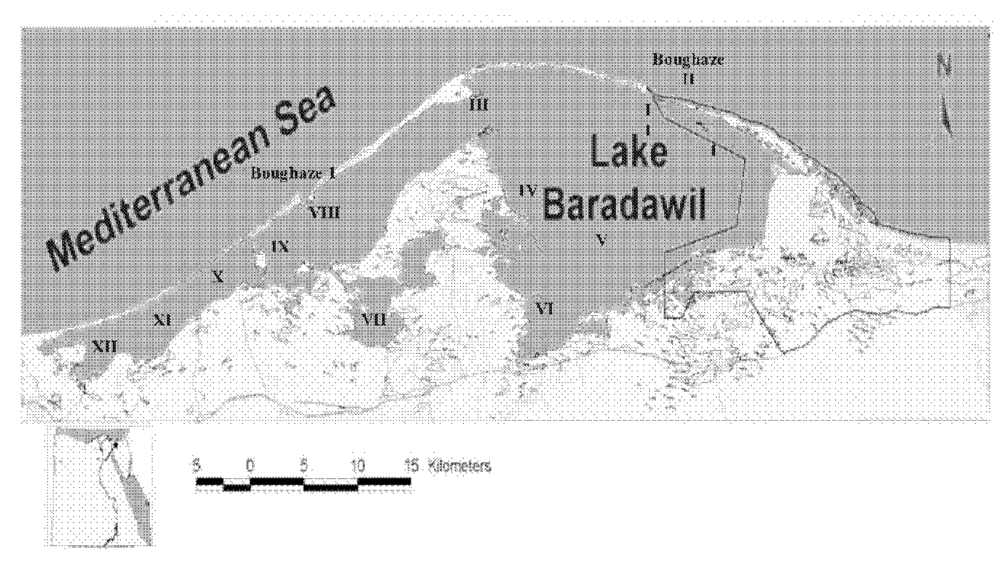


Fig. 7.1. **Map of the northern side of Egypt showing the location of Bardawil Lagoon and the selected stations (El-Shabrawy 2006).**

Table7.1. **Location of selected stations in Lake Bardawil (longitude and latitude)**

Station	Location	Station	Location
I	31° 09' 18 N 33° 19' 25 E	VII	31° 05' 35 N 32° 59' 18 E
II	31° 12' 27 N 33° 15' 43 E	VIII	31° 08' 11 N 32° 55' 75 E
III	31° 11' 78 N 33° 06' 24 E	IX	31° 06' 12 N 32° 53' 30 E
IV	31° 08' 96 N 33° 07' 92 E	X	31° 05' 67 N 32° 51' 18 E
V	31° 04' 50 N 33° 10' 13 E	XI	31° 04' 20 N 32° 48' 36 E
VI	31° 05' 81 N 33° 13' 65 E	XII	31° 03' 51 N 32° 46' 75 E

Table 7. 2. **Check list of zooplankton taxa recorded in Lake Bardawil during different time periods**

	1985	2002/03	present status
Protozoa			
Ciliophora spp.#		*	R
Codonella agalea Haeckel	*	*	R
Codonella amphorella Biedermann	*	*	R
Codonella aspera Kofoid & Campbell	*	*	MC
Cyttarocylis plagiostoma	*	*	VR
Dictyocysta minor Jörgensen	*		
Dictyocysta obtusa Jörgensen	*	*	VR
*Epiplocylis acuminata (*Daday) Jörgensen #		*	VR
*Favella ehrenbergi (*Clap & Lach.) Jörgensen#		*	R
*Favella serrata (*Möbius) Jörgensen	*	*	C
Helicostomella subulata (Ehr.)	*	*	R
Leprotintinnus bottnicus (Narolgvist) Jörgensen#	*	*	R
Metacylis mereschkowskii Kofoid & Campbell	*		
Petalotricha major Jörgensen #		*	VR
Ptychocylis minor Jörgensen #		*	VR
Rhobdonella elegans Jörgensen	*	*	VR
*Stenosemella nivalis (*Meunier*)* Kofoid & Campbell	*	*	R
Tintinnidium neapolitanum Daday	*		
*Tintinnopsis campanula (*Ehr.) Daday	*	*	R
Tintinnopsis cylindrica Daday	*	*	MC
Tintinnopsis lobiancoi Daday	*	*	R
*Tintinnopsis nucula (*Fol) Brandt	*	*	MC
Tintinnopsis beroidea Stein	*	*	MC
Tintinnopsis tocantinensis Kofoid & Campbell #		*	C
Undella sp.	*	*	VR
Foraminifera			
Globigerina bulloides d'Orbigny	*		
Orbilina universa d'Orbigny		*	VR
Copepoda			
Nauplius larvae		*	C
Cyclopoid copepodid		*	C
Calanoid copepodid		*	C
Harpacticoid copepodid		*	MC
Lucicutia flavicornis Claus	*		
Lucicutia ovalis Giesbrecht	*		
Temora longicornis müller	*		
Acartia clausii Giesbrecht	*	*	MC
Paracartia latisetosa Krica. #		*	R
Calanus finmarchisus Gunnerus	*		
Eurytemora hirunoloides Nordqvist	*	*	VR
Paracalanus parvus Claus #		*	R
Centropages ponticus Karavaev #		*	C
Sapphirina opalina Dana	*		
Sapphirina angusta Dana	*		
Parapontella brevicornis Lubbock	*		
Parapontella sp.	*		
Oithona nana Giesbrecht #		*	C
Oithona plumifera Baird #		*	MC
Corycaeus clausi F. Dahl	*		
Isias clavipes Boeck	*		
Euterpina acutiforns Dana	*	*	C
Microsetella norvegica Boeck	*	*	R
Amallothrix auropecten Giesbrecht	*		
Echinocomptus spp.	*		

	1985	2002/03	present status
Canuella sp. #		*	VR
Harpacticus littoralis Sars #		*	R
Metis jousseaumei Richard #		*	VR
Cladocera			
Bosmina maritima Müller	*		
Evadne spinifera Müller	*	*	R
Evadne tergestina Claus #		*	R
Podon polyphemoides Leuckart #		*	VR
Rotifera			
Synchaeta calva Ruttner-Kolosko	*	*	MC
Synchaeta sp. #		*	R
Coelentrates			
Rhizostoma pulmo Merci.	*	*	VR
Obelia spp. #		*	R
Cotylorhiza tuberculata Agassiz	*		
Pteropods			
Limacina inflata D'orbigny	*	*	C
Cheatognatha			
Sagitta setosa Müller #		*	R
Appendicularians			
Oikopleura longicauda Vogt #		*	R
Meroplankton			
Polycheate larvae	*	*	C
Cirripedia larvae	*	*	MC
Mollusca larvae	*	*	C
Echinodermata larvae	*	*	VR
Ostracod spp.	*	*	R
Chironomus larvae		*	VR
Mysis sp.		*	VR
Osteichthyes egg & embryos		*	VR
Nematoda (free living)	*	*	VR

C: Common species
VR: Very rare species
1985: after Fouda *et al.* 1985
2002/2003: after El-Shabrawy 2006
MC: Moderate Common Species
R: Rare Species
#: new recorded species

7. 2 DISTRIBUTION OF COMMON AND LESSCOMMON SPECIES

7.2. 1 Protozoa

7.2.1.1 *Favella serrata*

Favella serrata was found to be the most common and dominant protozoan species in Bardawil Lagoon, comprising 27.1 % of total protozoan density. The density of this species ranged between 60,000 ind. m^{-3} at station VIII in spring and 250 ind. m^{-3} in autumn at stations I, IV, XII, with an overall average of 2995 ind. m^{-3}. Regarding seasonal variation, spring is the season of highest production of this species (avr. 8792 ind. m^{-3}), in autumn it is hardly represented or even absent at stations V, VI, VI (avr. 729 ind. m^{-3}) (Fig. 7. 2). There is a tendency towards an increase in abundance of this species at station VIII (mean 16375 ind. m^{-3}), while stations I and XII showed the lowest yield, with a mean of 688 ind. m^{-3}.

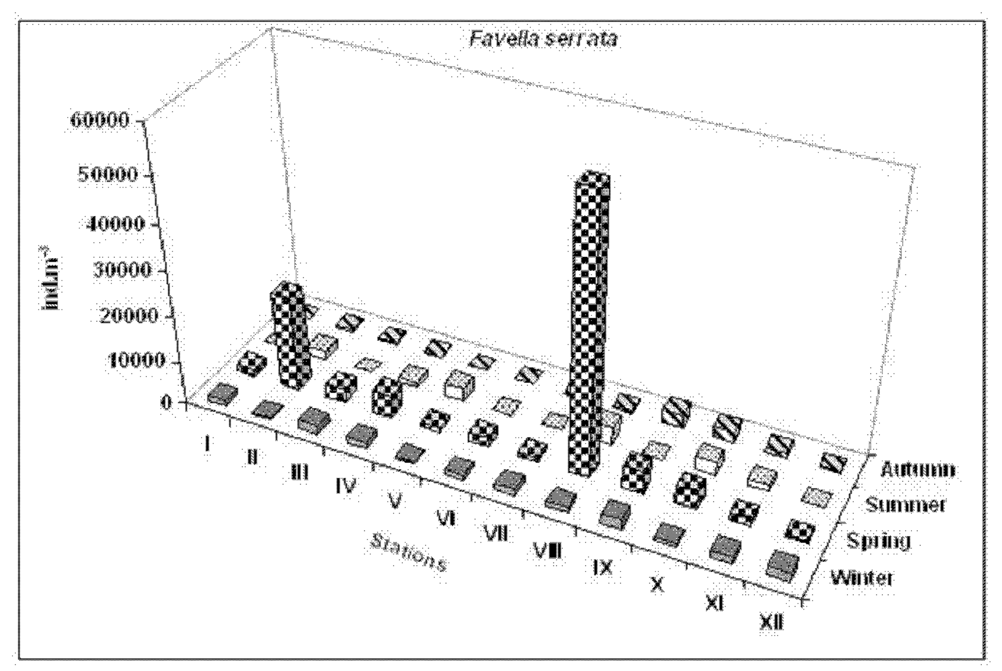


Fig. 7. 2. **Distribution and seasonal variation of *Favella serrata***

7.2.1.2 *Tintinnopsis tocaninnus*

Tintinnopsis tocaninnus occupied the second predominant position among protozoa: 13.1 % of total protozoan population density. *T. tocaninnus* had the highest density in winter, with an average density of 4083 ind. m^{-3}, and a more reduced density in spring (avr. 833 ind. m^{-3}), and minimum density in autumn (avr. 333 ind. m^{-3}). Spatially, stations V and VIII (in front of Boughaz I and II) maintained the perennial and highest occurrence of this species, with a yield of 3625 and 4875 ind. m^{-3} respectively (Fig. 7.3). Abdel Rahman (1997) and El-Serehy *et al.* (2000) respectively, recorded this species at Gulf of Suez and Suez Canal.

7.2 Copepoda

7.2.2.1 *Nauplius* larvae

Nauplii larvae, numerically dominated the copepod fauna; usually contributed more than 63 % to total copepods density. They peaked in spring and summer, with a mean value of 81,667 and 93,958 ind. m^{-3}, respectively. The lowest population density of these larvae occurred in winter (avr. 18,147 ind. m^{-3}). Spatially, stations VII and X presented the highest density of these larvae, while the lowest crop was recorded at station III (Fig. 7. 4).

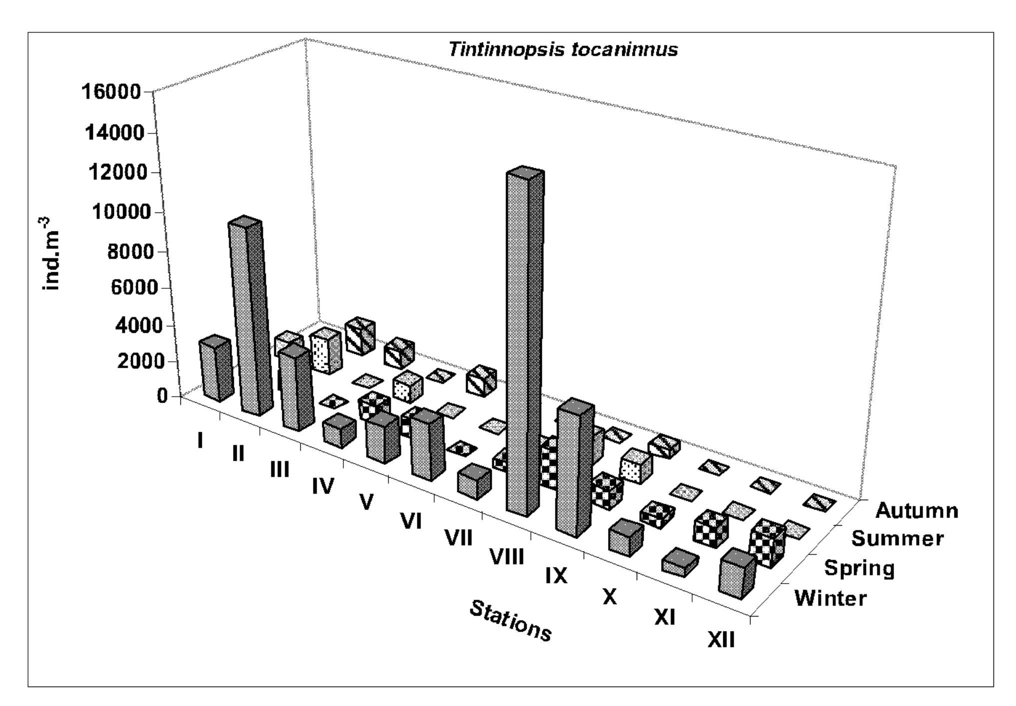


Fig. 7.3. Distribution and seasonal variation of *Tintinnopsis tocaninnus*

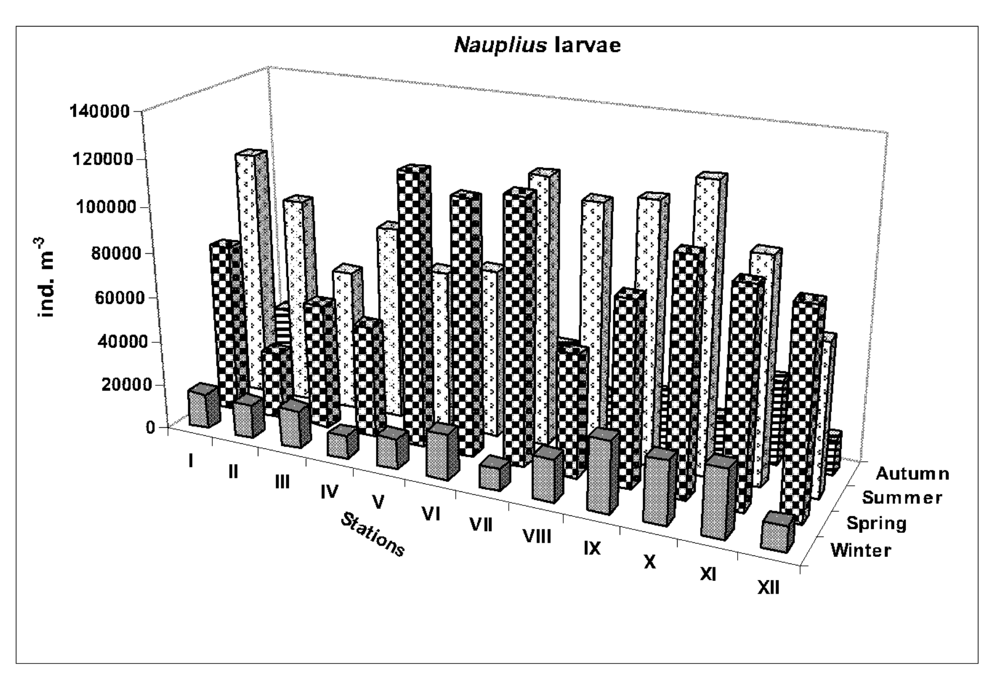


Fig. 7. 4. Distribution and seasonal variation of *Nauplius* larvae

7.2.2.2 Cyclopoid copepodid

Cyclopoid copepodid contributed 11.4 % of total copepods density (range 5.4 – 15.5 %) as shown in Fig. (7.5). The highest occurrence of these copepodid stages was recorded in summer (avr. 18958 ind. m^{-3}), while they persisted in densities around 5000 ind. m^{-3} during the rest of seasons. Stations IX, X and XI (west of the Lagoon) show the highest density of these larvae (avr. 12000, 12313 and 11000 ind. m^{-3} respectively), while the lowest density occurred at stations I and VI (avr. 5688 and 5125 ind. m^{-3} respectively).

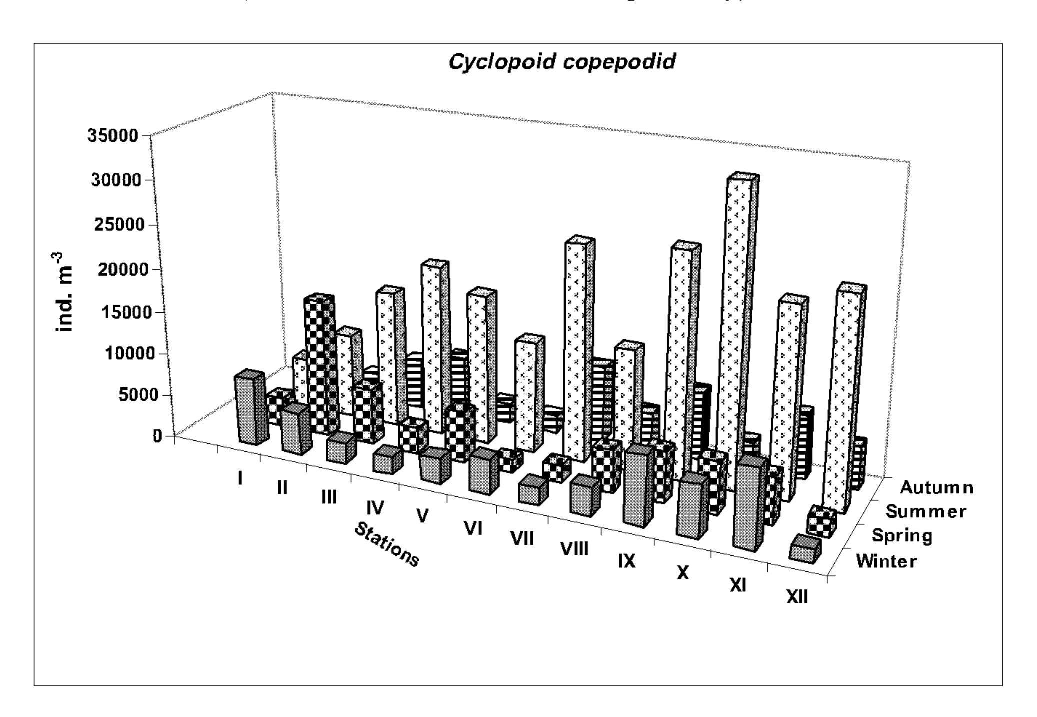


Fig. 7. 5. **Distribution and seasonal variation of cyclopoid copepodid**

7.2.2.3 Calanoid copepodid

Calanoid copepodid stages are more abundant than adults, contributing 3 % of total copepods density (range 1.5 : 3.8 %). The occurrence of these stages are well represented in summer (avr. 5167 ind. m^{-3}), while the lowest mean of 958 ind. m^{-3} was recorded in winter (avr. 958 ind. m^{-3}), with an overall average of 2214 ind. m^{-3}. The spatial distribution of these larvae showed a high density (average 8875 ind. m^{-3}) at station II (in front of Boughaze II), with a high peak of 20000 ind. m^{-3} in summer. Stations V, VI, XII showed the lowest crop (avr. 750 and 125 ind. m^{-3} respectively) (Fig. 7. 6). The presence of copepod larval stages (nauplii and copepodid) all the year round indicates the continuous reproduction of copepods all the year (Raymont 1983). Nauplii and copepodid stages were the major component of copepod population in the whole Egyptian Mediterranean and Red Sea coast (Dowidar & El-Maghraby 1970, Hussien

1977, Abdel Rahman 1997, El-Sherbiny 1997). Five broads representing five generations over the year were expected for *Oithona nana*, *Euterpina acutifrons*, and *Paracalanus parvus* (common species in Bardawil Lagoon) in the south eastern Mediterranean (Dowidar & El-Maghraby 1970).

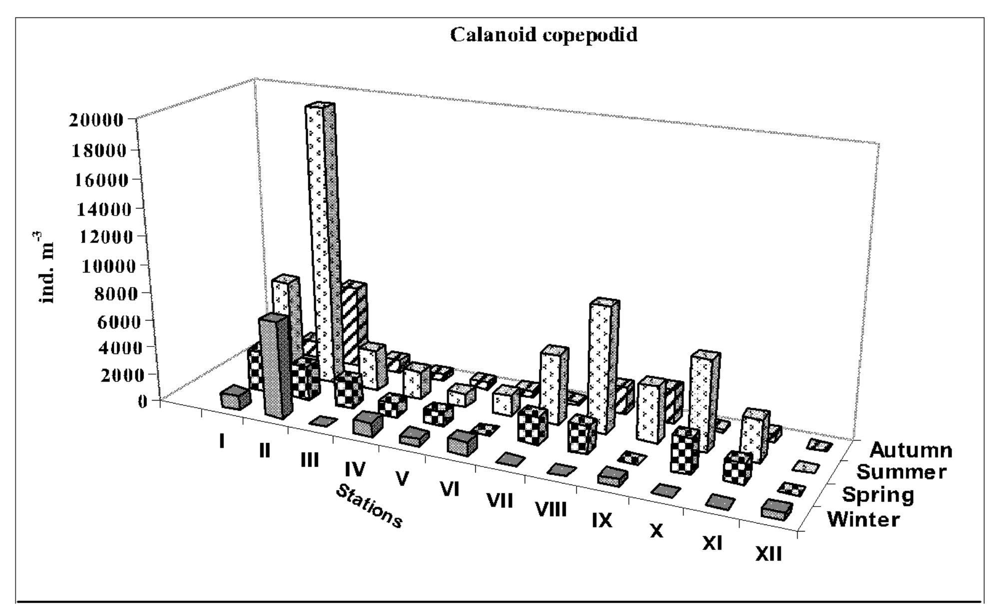


Fig. 7. 6. **Distribution and seasonal variation of calanoid copepodid**

7.2.2.4 *Oithona nana*

The numerically dominant copepod species was obviously *O. nana*, which contributed 59.1 % of total adult copepods density (range 26.2 – 77.6 %). *O. nana* exhibited clear peak in abundance only during summer (aver. 14,583 ind. m^{-3}). It persisted with a population density fluctuated within 2,000 ind. m^{-3} during the rest of the year. Spatially, station X maintained the highest density (aver. 8,875 ind. m^{-3}), while the lowest density of 2875 ind. m^{-3} occurred at station VI (Fig. 7. 7). *Oithona nana* is distributed in the tropical and subtropical waters of the Pacific and Indian oceans with high density in the tropical water (Nishida 1985). It has frequently been recorded from tropical and subtropical Atlantic (Grice 1960, Gonzalez & Bowman 1965) and the Mediterranean (Fruchtl 1920). *O. nana* is common not only in the open sea but also in estuaries and enclosed bays in the tropical regions (Grice 1960). *O. nana* is highly tolerant to wide ranges of temperature and salinity variation (Dowidar 1965) and found mainly in the surface shallow water (Boxshall 1977). Previous studies showed the highest density of this species in summer at Egyptian Mediterranean water, Lake Timsah, and Suez Gulf (Dowidar & El-Maghraby 1970, Hussien 1977 & 1997, Abou Zeid 1990, Abdel Rahman 1993). *O. nana*

was the most important species in Doha Harbor (Arabian Gulf), comprising 34.4 % of total copepods, with highest density in summer.

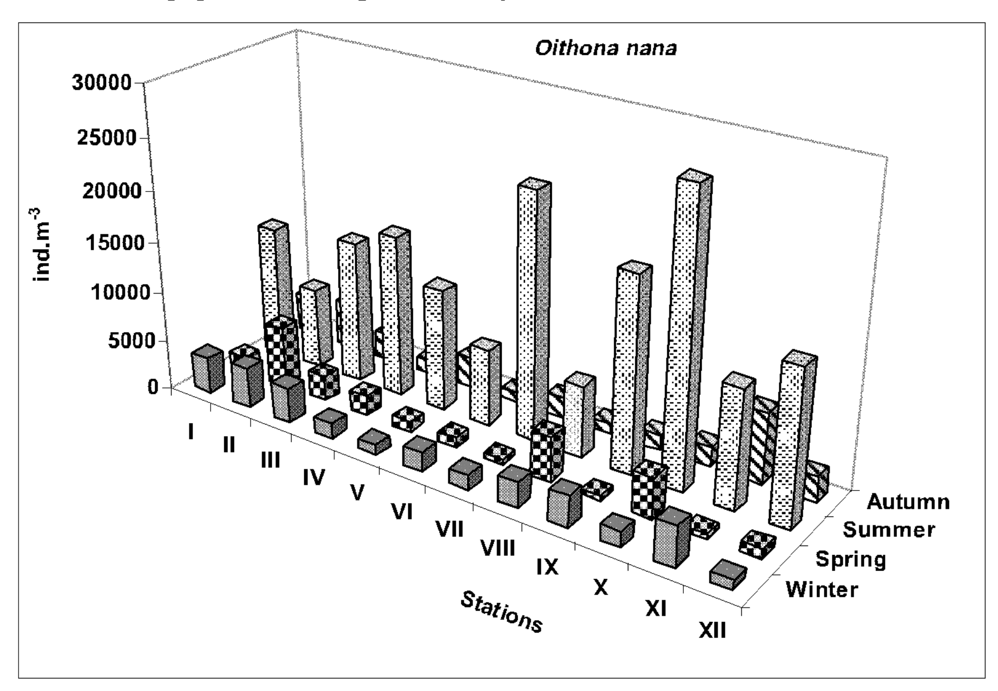


Fig. 7. 7. **Distribution and seasonal variation of *Oithona nana***

7.2.2.5 *Acartia clausii*

As shown in Fig. (7. 8), the occurrence of this species is highly restricted to winter and spring in Bardawil Lagoon. The highest flourishing occurred in spring with a major peak of 5000 ind. m^{-3} at station X. *A. clausii* is weakly represented in winter and totally missed during summer. Few individuals were recorded at station VIII in autumn. *A. clausii* is Atlanto-Mediterranean, anti-lessepsian migrant (Fox 1927). It is the most common Acartiidae species in the entire Ponto-Mediterranean province (Belmonte & Potenza 2001).

A. clausii is a widely distributed euryhaline and eurythermic species previously recorded along the Egyptian Mediterranean waters (Hussien 1977, Nour El-Din 1987, Abdel Aziz 1997), as well as in brackish water of Lake Manzalah (El-Maghraby *et al.* 1963).

7. 2.2.6 *Centropagus potincus*

C. potincus is an aestival species, with highest occurrence in summer (avr. 2,042 ind. m^{-3}), with a high peak of 11,000 ind. m^{-3} at station VIII (in front of Boughaz I). Spring and autumn showed the lowest crop with a mean density around 300 ind. m-3 (Fig. 7. 9). The population density of this species made up 9.4 % by total adult copepod numbers (range 4.1 – 15.1 %). *C. potincus* is a

pelagic, neritic species, previously recorded in Suez Canal and eastern Mediterranean (Sandra *et al.* 1996, Abdel Rahman 1997).

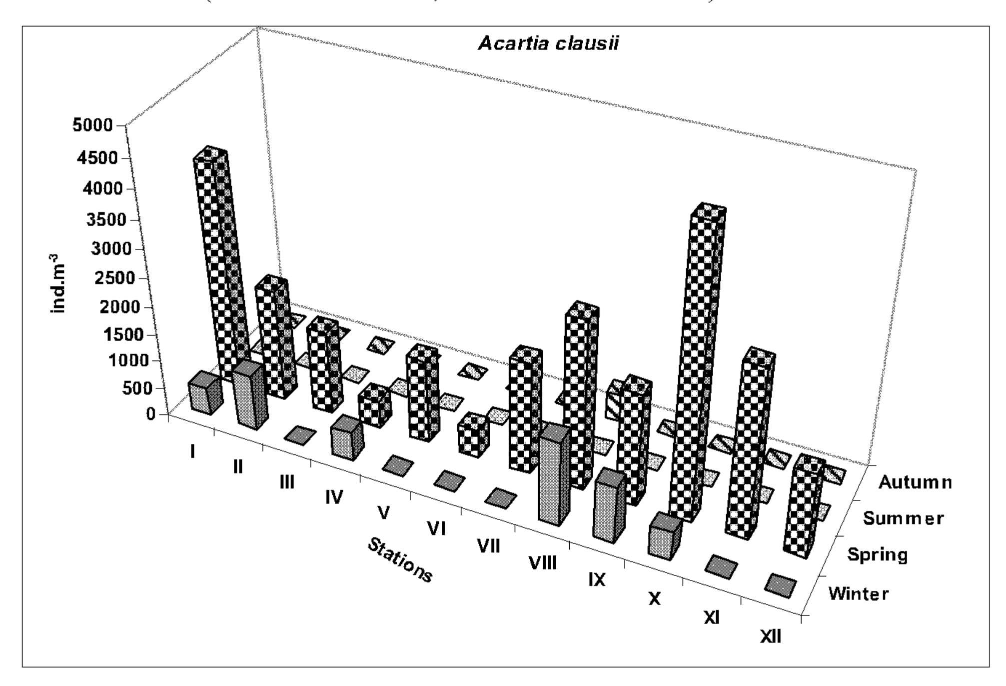


Fig. 7. 8. **Distribution and seasonal variation of *Acartia clausii***

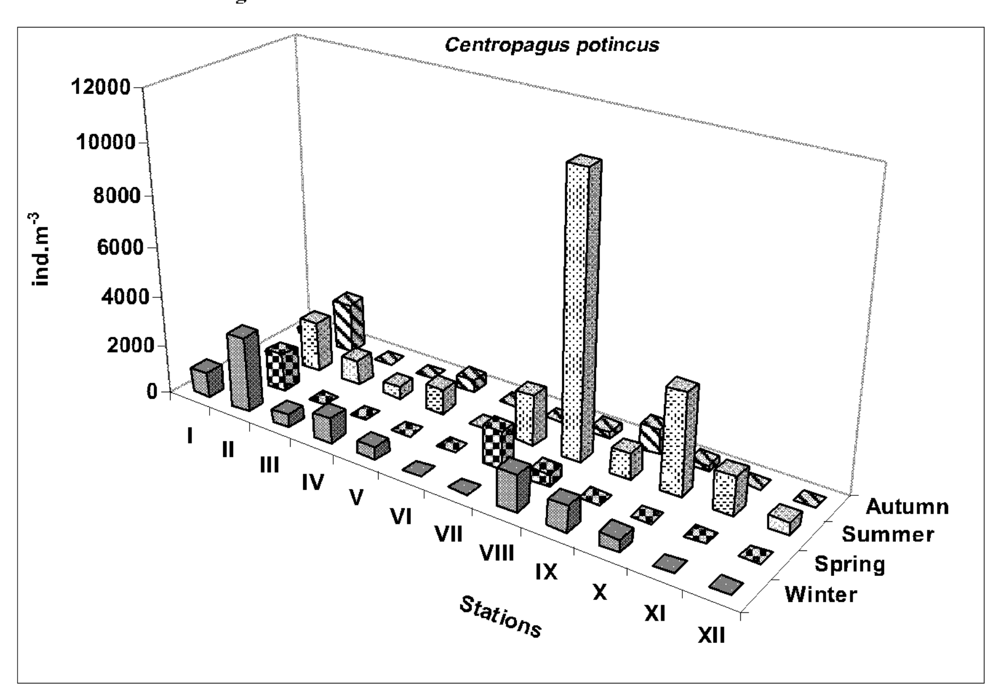


Fig. 7. 9. **Distribution and seasonal variation of *Centropagus potincus***

7.2.2.7 *Euterpina acutifrons*

E. acutifrons is a perennial species, that makes up 12.4 % (range 4.9 – 31.9 %) of total adult copepods density. In contrast to the previous mentioned copepod species, *E. acutifrons* is peaked in spring, with a pinnacle of 11,000 ind. m^{-3} at station I. The species population was highly abated in autumn (Fig. 7.10). *E. acutifrons* was recorded in Gulf of Suez and Suez Canal (Gurney 1927, Abdel Rahman 1993 & 1997), Lake Timsah (Abou Zeid 1990) Eastern Mediterranean (El-Maghraby 1965, Saleh & Tomas 1970 , Hussien 1997). It was previously recorded in Bardawil Lagoon in 1980s (Fouda *et al.* 1985).

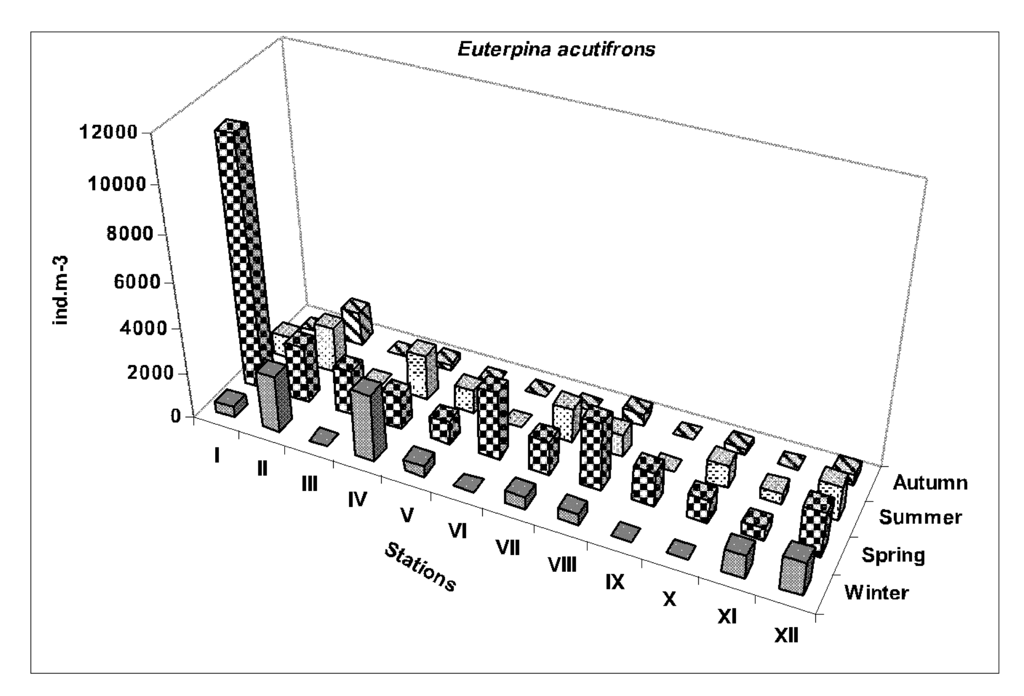


Fig. 7. 10. **Distribution and seasonal variation of *Euterpina acutifrons***

7.2.2.8 *Synchaeta calva*

S. calva was a moderately common species in Bardawil Lagoon during 2002/2003. The population density of this species shows two obvious peaks of 22,000 and 15,000 ind. m^{-3} at stations IV and X during spring and autumn respectively. Summer showed the lowest occurrence of this species.

7.2.2.9 Polychaete larvae

Polychaete larvae represent a most common meroplankton organisms in Bardawil Lagoon, owing to its perennial occurrence during the different seasons. Spring is the season of the highest densities of these larvae with obvious peaks of 20,000 and 30,000 ind. m^{-3} at stations II, VIII and III respectively. On the other hand, there was a severe drop in species densities in autumn, when it was faintly represented or even absent at the majority of

stations (Fig. 7. 11). Abdel Rahman (1993) and Dorgham & Hussien (1997) recorded the highest standing crop of these larvae at Suez Gulf and Doha Harbor during spring and autumn, respectively.

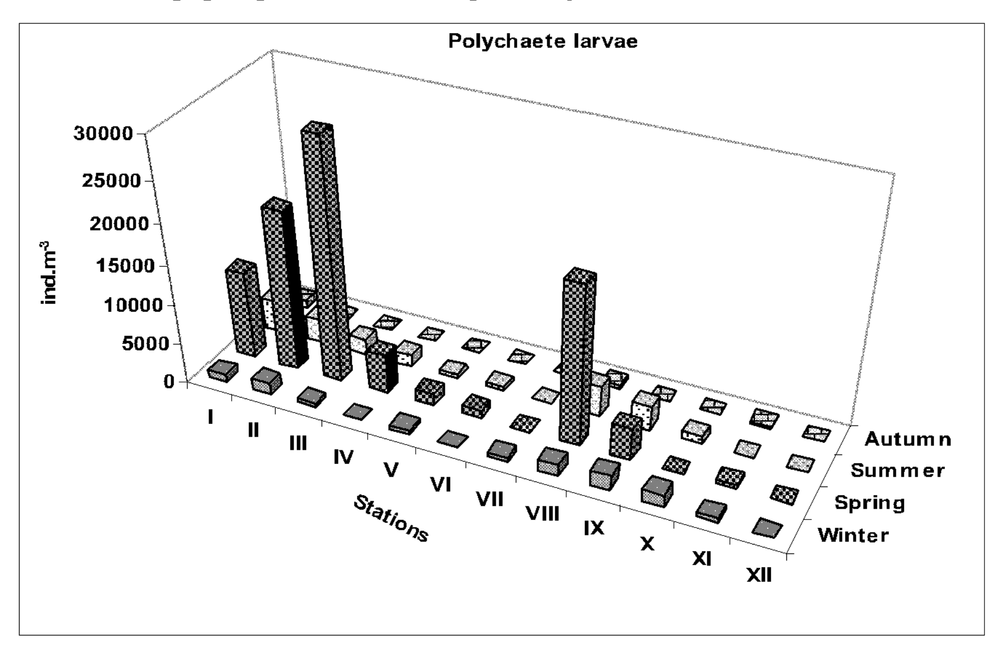


Fig. 7. 11. Distribution and seasonal variation of polychaete larvae

7.2.2.10 Mollusca larvae

These larvae are another example for the most common meroplankton in the Lagoon. The population density of these larvae occurred in spring (avr. 2625 ind. m^{-3}), with a major peak of 40,000 ind. m^{-3} at station II. The lowest occurrence was recorded in winter (avr. 542 ind. m^{-3}) (Fig. 7. 12). Molluscan larvae represented the second important group of zooplankton, forming 20.3 % of total zooplankton at north Red Sea (El Sherbiny 1997). They occupied the second predominant position among zooplankton group in the natural reserved area at south Sinai Coast (Abdel Rahman 1997). In accordance with the present study, El-Rashedi (1992) reported that spring was the breeding season for Mollusca at Sharm El Shiekh (Gulf of Aqaba), while Dorgham & Hussien (1997) recorded the peaks of these larvae in winter and summer at Doha Harbor (Arabian Gulf).

7.3 POPULATION DYNAMIC AND COMMUNITY STRUCTURE OF ZOOPLANKTON

The zooplankton community is represented mainly by the holoplankton groups (Protozoa, Copepoda, Caldocera, Coelentrata, Chaetognatha and Rotifera), which contributed about 93 % of the total zooplankton density. Meroplankton made up about 6.7 % of total zooplankton, composed of the

larvae of Mollusca, Polychaeta, Cirripedia, Decapoda, Echinodermata and other groups as Ostracoda and *Chironomus* larvae (Fig. 7. 13).

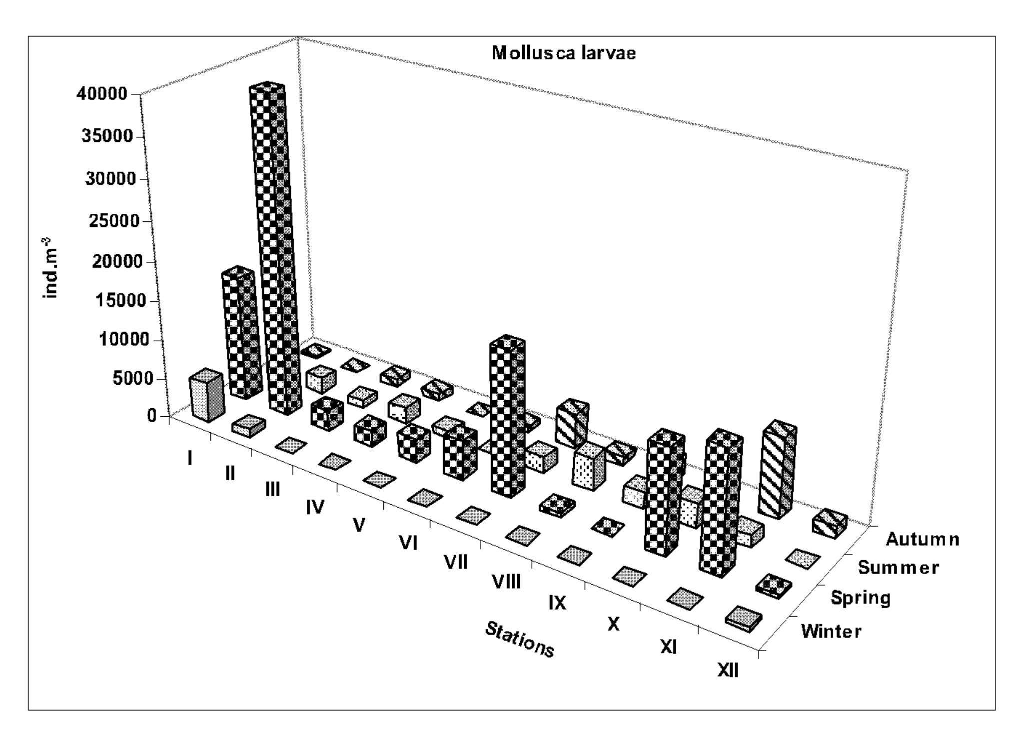


Fig. 7. 12. **Distribution and seasonal variation of Mollusca larvae**

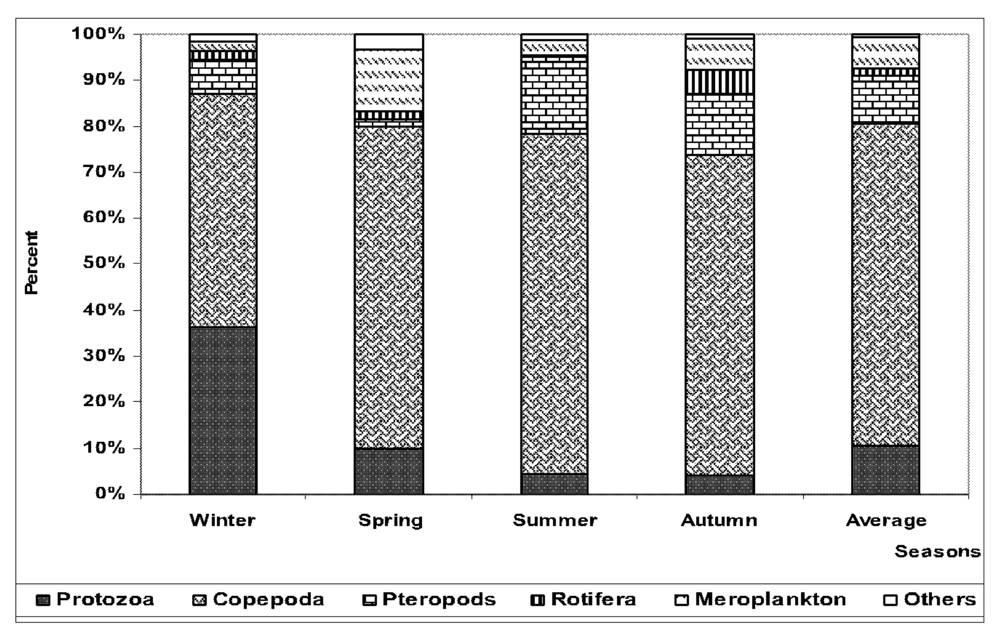


Fig. 7. 13. **Community composition of total zooplankton in Lake Bardawil**

The density of zooplankton in Lake Bardawil is subjected to significant seasonal and regional variations. As shown in Fig. (7. 14), zooplankton is more abundant in spring and summer, with a mean of 134,958 and 185,333 ind. m^{-3} respectively. There is a severe depletion in zooplankton density during winter and autumn with a mean of 56,833 and 51,479 ind. m^{-3} respectively. Spatially, a mutual increase and decrease in zooplankton density was noticeable from station to another. Stations X and II maintained the highest densities of 137,938 and 120,875 ind. m^{-3} respectively, while the lowest densities of 71,063 and 75,125 ind. m^{-3} occurred at stations XII and III, respectively. In contrast to 2002/03 study, Fouda *et al.* (1985) recorded the highest peak of plankton at Raabah station (station XII).

Copepoda is most abundant and ubiquitous zooplankton taxon in Bardawil Lagoon, forming 69.9 % (range 51.2 – 74.1 %) of total zooplankton density. Summer is the season of highest densities of these invertebrates (avr. 137,333 ind. m^{-3}) with a high peak of 198,500 ind. m^{-3} at station X. Winter sustained the lowest density, with a mean of 29,083 ind. m^{-3} (Fig. 7. 15).

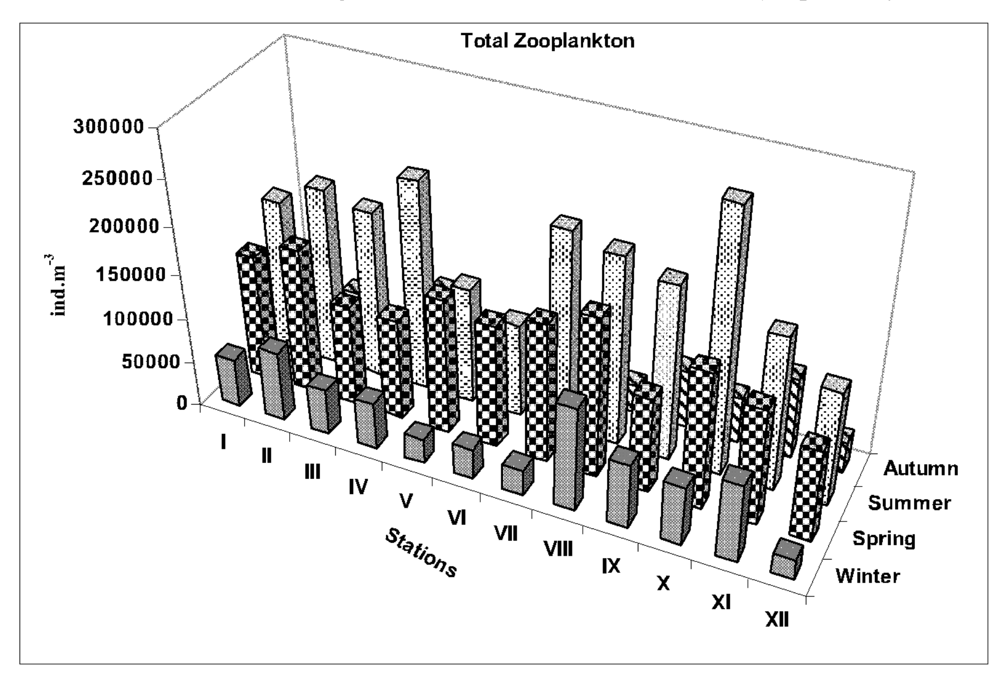


Fig. 7. 14. **Distribution and seasonal variation of total zooplankton**

El-Shabrawy (2006) identified 28 copepod species during 2002/2003 study in Bardawil Lagoon, but Fouda *et al.* (1985) recorded only 16 species during 1980s; dominant mainly by *Acartia clausii*. *Oithona nana* is the most common and dominant copepod species, recorded in a high density during the whole period of investigation. *A. clausii* appeared during winter and spring.

Nauplii and copepodid stages proved to be the most common forms, forming 72.7 and 14.9 % of total copepod density, while adult stages of copepods contributed 12.4 % (Fig. 7. 16).

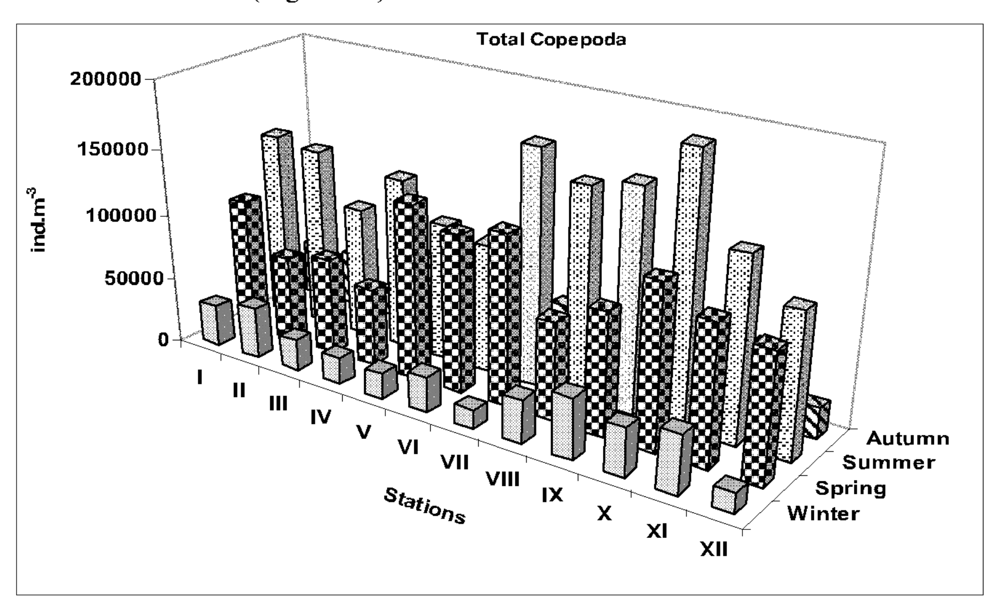


Fig. 7. 15. **Distribution and seasonal variation of total Copepoda**

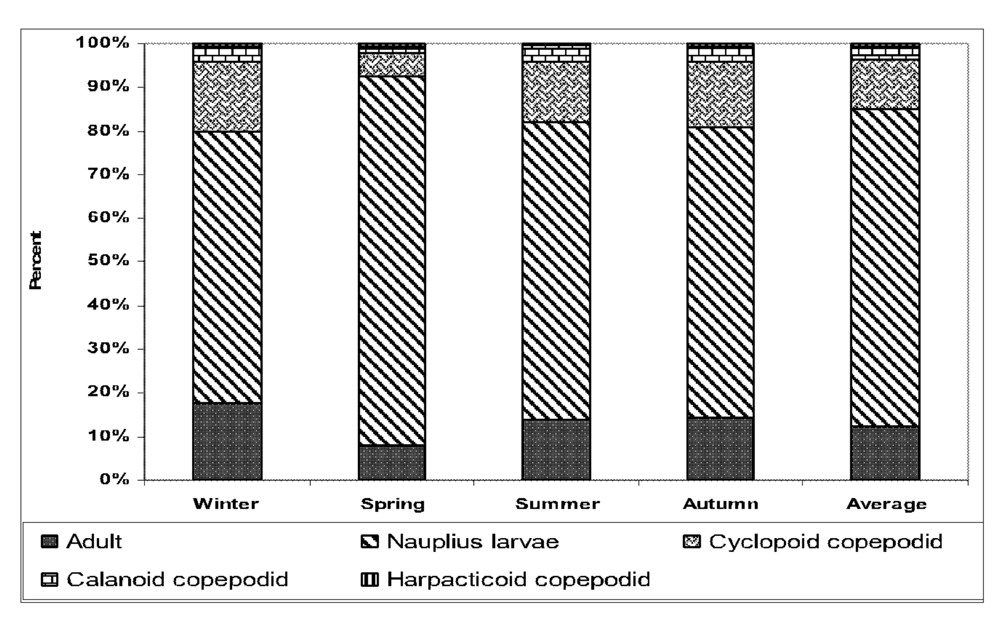


Fig. 7. 16. **Community composition of total Copepods in Bardawil Lagoon**

Protozoa is one of the most common and diverse zooplankton group in Bardawil Lagoon. Five protozoan species were identified during 2002/2003 study. Fouda *et al.* (1985) previously recorded 21 protozoan species, *Tintinnopsis labiancoi* was the most widespread species in the Lagoon. *Tintinnopsis tocanensis* and *Favella panamensis* were the most common and dominant protozoans. Regarding seasonal variation, winter maintained the highest densities of these organisms with a mean of 20,708 ind. m^{-3} , contributing 36.4 % of total zooplankton account. The lowest population density was recorded in autumn with a mean of 2042 ind. m^{-3} , forming 4 % of total zooplankton number. Spatially, the highest flourishing of these protest occurred at station VIII (in front of Boughaz I) with two remarkable peaks of 77,000 and 75,000 ind. m^{-3} during winter and spring owing to high abundance of *T. tocanensis* and *F. serrata*, respectively (Fig. 7. 17).

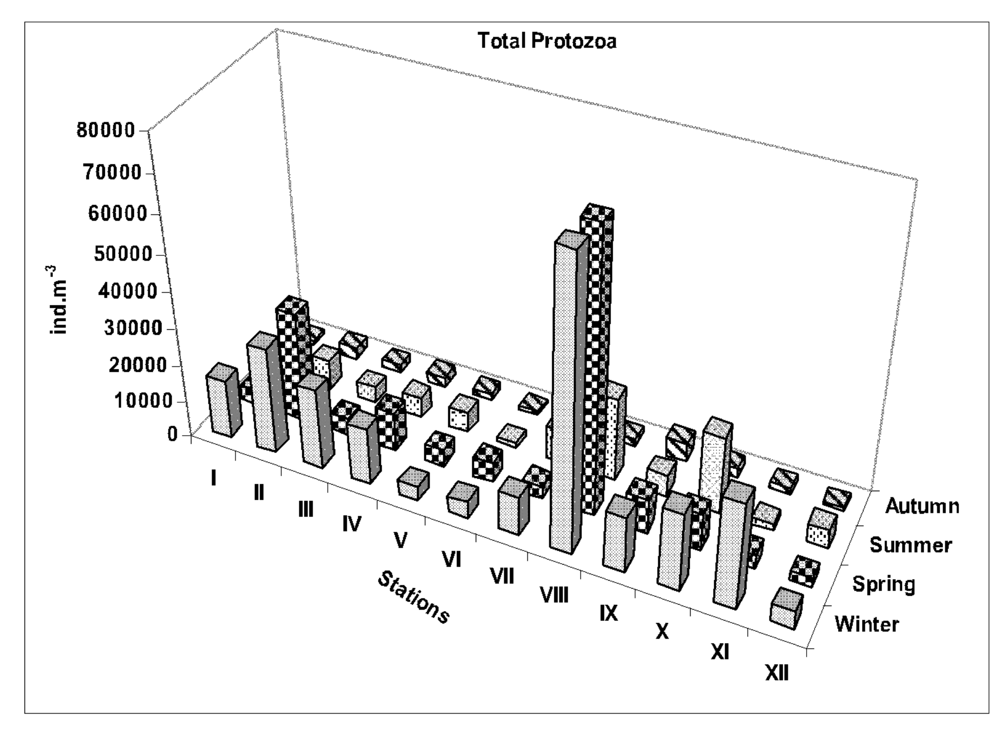


***Fig. 7. 17.* Distribution and seasonal variation of total Protozoa**

Pteropoda is another example for the most common zooplankton group in Bardawil Lagoon. *Limacina inflata* was the only species, representing this group during 2002/03 and contributed 10.3 % of total zooplankton density. The population density of this species reached its maximum in summer (aver. 31,250 ind. m^{-3}) with an obvious peaks of 77,000 and 85,000 ind. m^{-3} at stations III and IV, respectively (Fig. 7. 18). On the other hand, spring sustained the lowest density, with a mean of 1875 ind. m^{-3}. Hussien (1977 & 1997) recorded a

remarkable peak of this species during autumn in the Mediterranean offshore neritic water. However, Nour El Din (1987) found that the highest density of pteropods occurred in summer. *L. inflata* constituted 9.7 % of total zooplankton, attaining its maximum in summer at Doha Harbor (Dorgham & Hussien 1997).

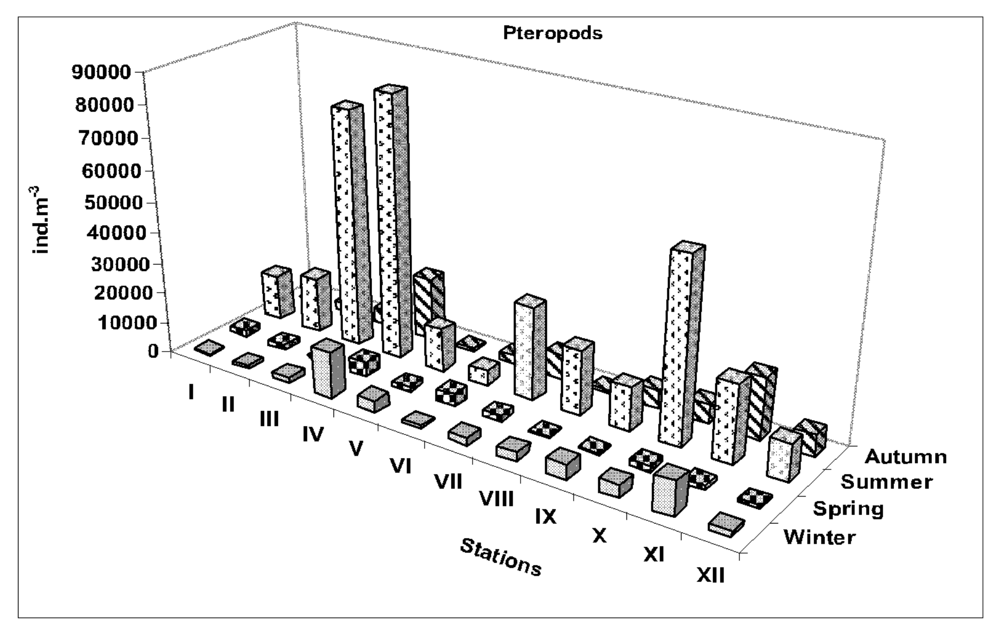


Fig. 7. 18. **Distribution and seasonal variation of Pteropoda**

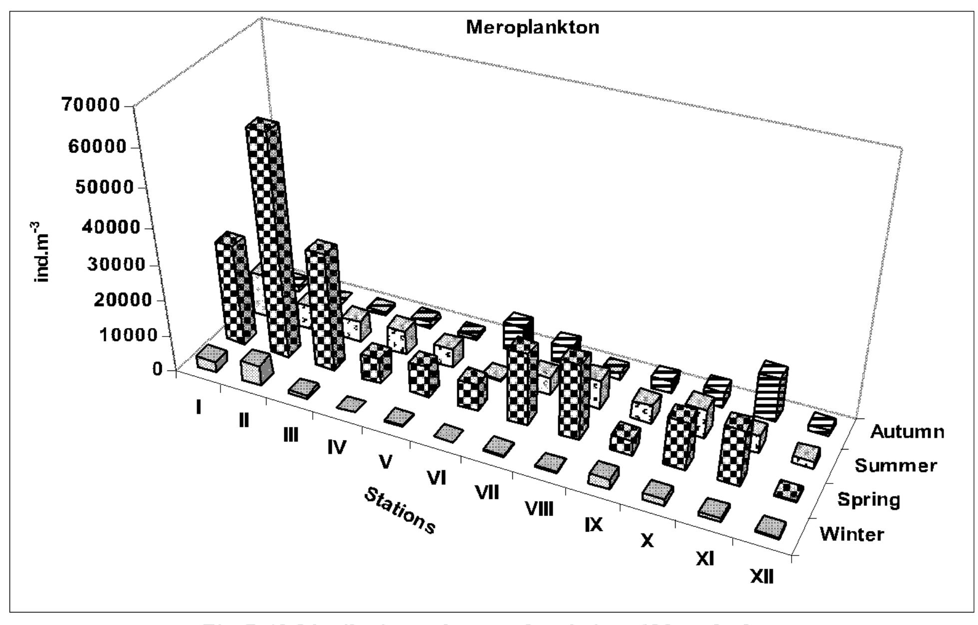


Fig. 7. 19. **Distribution and seasonal variation of Meroplankton**

Meroplankton group was represented by the larvae of the benthos organisms, and contributed about 6.7 % of total zooplankton density. Spring is the season of the highest production (aver. 18,250 ind. m^{-3}) with a peak of 61,000 ind. m^{-3} at station II. The lowest density occurred in winter with a mean of 1346 ind.m^{-3} (Fig. 7. 19). Molluscan and polychaete larvae are the common and perennially occurred during most of the year, while the others were rarely recorded.

Rotifera group, represented mainly by *Synchaeta calva* and *Synchaeta* sp., constituted 1.6 % of total zooplankton account. Rotifera showed a high peak of 22,000 ind. m^{-3} at station IV in spring (Fig. 7. 20), another small peak of 15,000 ind. m^{-3} was recorded at station X in autumn. A remarkable drop in population density was noticed in summer (avr. 542 ind. m^{-3}), owing to disappearance of these organisms at the majority of stations.

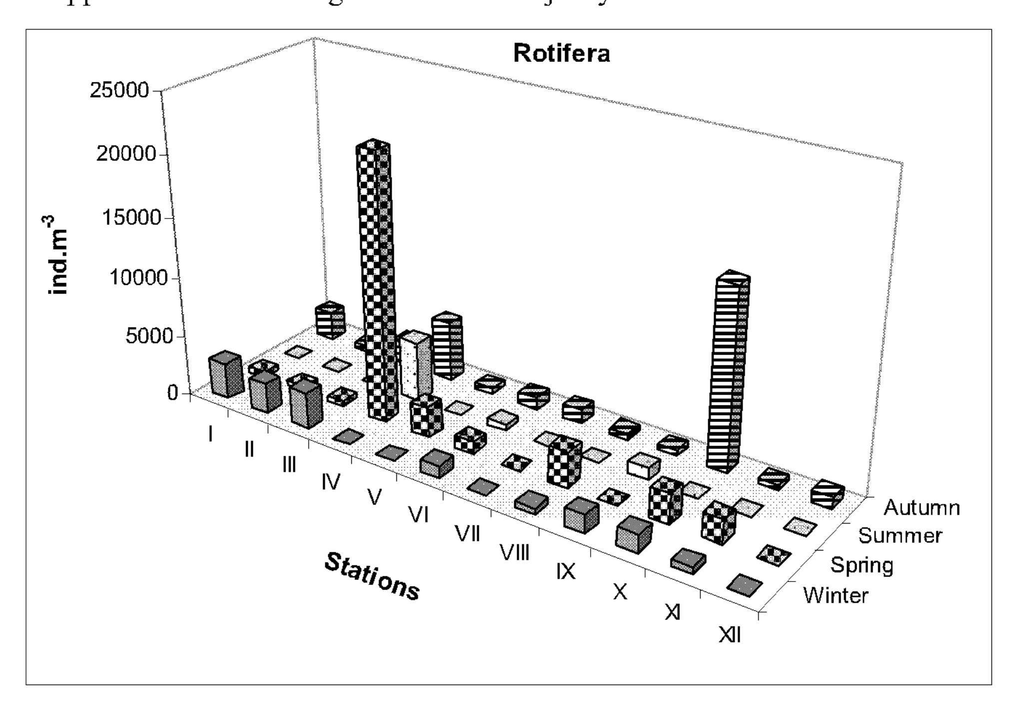


Fig. 7. 20. **Distribution and seasonal variation of total Rotifera**

7.4 FACTORS AFFECTING ZOOPLANKTON COMMUNITY STRUCTURE

The main objective of plankton ecologists is to identify the factors that influence the distribution, abundance, biodiversity and community structure of the plankton, but this ambition is often faced by the complexity of the nature of the environment. Regulation of seasonal succession and distribution of zooplankton in the hyper-saline Bardawil Lagoon is expected to reflect a mix of abiotic and biotic conditions. Temperature, salinity, nutrient salts and

phytoplankton assemblage proved to be the main factors controlling zooplankton occurrence and abundance in Bardawil Lagoon.

Water temperature exerts a significant influence on zooplankton population dynamics, not only by its direct influence on embryonic development, reproduction activities and rate of molting, but also because it is an important characteristic of the determinative situation of the environment. In stenothermal species particularly, temperature is a crucial factor determining occurrence and fertility (Hofmann 1977). During 2002/03 study, the water temperature showed a positive correlation with the standing crop of total zooplankton, total copepods, total pteropods and *Centrpagus potincus* (r = 0.75, 0.81, 0.80 and 0.63, respectively), while total Protozoa, *T. tocaninns* were inversely correlated with temperature (r = -0.71 and -0.84 respectively). In agreement with this study Abdel Aziz (1997) and Nour El Din (2001) found a negative correlation between *Acrtia clausii* and temperature. Abdel Aziz & Dorgham (2002) found a significant correlation between temperature and Copepoda (r = 0.64) in the site of Abou Qir Bay in spring.

Salinity has long been considered an important factor that influences the composition and dynamics of aquatic ecosystem. Salinity has a great effect on zooplankton community structure in Bardawil Lagoon.

The population density of total Protozoa, meroplankton, *T. tocaninns, Favella serrata, Acrtia clausii, Euterpina acutfrons* and *Synchaeta calva* were negatively correlated with salinity (r = -0.89, -0.66, - 0.60, -0.71, -0.64, -0.23, respectively). *Limacina inflata* (pteropods) was positively correlated with salinity (r = 0.68). Nour El Din (2001) mentioned that *Acartia clausii* disappeared in some areas of Lake Bardawil, with salinity above 48 ‰, indicating that this value was the maximum salinity threshold that *A. clausii* could withstand. El- Shabrawy (2006) confirms that, *A. clausii* totally disappeared from plankton hauls in summer and autumn, when salinity reached its maximum to 53 ‰. Moreover, he shows that *Oithona nana*, which considered as the most dominant zooplankter in the Lagoon, is eruythermal and eruyhaline species.

Nutrient salts represent the natural fertility of the water on which primary productivity and ultimately fish production depend. There is an obvious increase in nitrate and soluble phosphate values from a range of 0.04 0.16 mg l^{-1} and 0.009 – 0.42 mg l^{-1} in 1988 (Siliem 1989) to 1.1 – 5.8 and 0.01 – 0.89 mg l^{-1} in 1998 (Anon 2000) respectively. Correlation matrix shows the great effect of nutrient salts on zooplankton community structure in Bardawil Lagoon. Nitrate is positively correlated with total zooplankton, Copepoda, Pteropoda and *Centropagus potincus* (r = 0.51, 0.6, 0.84, 0.66 respectively), and negatively correlated with total Protozoa, *T. tocantinensis*, and *Acartia clausii* (r = -0.8, -0.75 and 0.52, respectively). A positive correlation was recorded between

soluble phosphate and total zooplankton, Copepoda, meroplankton, *F. serrata*, *Acartia clausii* and *Euterpina acutifrons* (r = 0.83, 0.76, 0.75, 0.72, 0.66 and 0.87, respectively). In accordance with the present study Abdel Aziz & Dorgham (2002) found a positive correlation between nitrate and phosphate (r = 0.77) and standing crop of Copepoda during autumn in western harbor of Alexandria

The pH values are related to several other chemical parameters, which are correlated in turn with zooplankton density. The hydrogen ion concentration in Bardawil Lagoon is on the alkaline side, it fluctuates between 7.7 – 8.7 (Anon 2000). Although the range of pH values in Bardawil Lagoon was narrow, it showed a negative correlation with total Protozoa, *T. tocantinensis* and *Euterpina acutifrons* (r = -0.95, -0.72 and -0.52, respectively). O'Brein & De Noyelles (1972) mentioned that the composition of zooplankton can be influenced by changes in pH.

In conditions of increasing eutrophication, the number of zooplankton species gradually decrease and generally the faunistic assemblage is simplified (Siokou-Franguo *et al.* 1998). The low species-richness under eutrophication conditions and the abundance of a few species in a particular biotope result from their tolerance of the environmental variability and their capability for optimum exploitation of food resources. This variable tolerance results from special physiological adaptations of the organisms (Gaudy 1984). There is an obvious increase in nitrate and soluble phosphate from 0.04 – 0.16 mg/l and 0.009 – 0.42 mg l^{-1} in 1988 (Siliem 1989) to 1.1 – 5.8 mg l^{-1} and 0.02 – 0.89 mg l^{-1} in 1999 (Anon 2000). Progressive increase in nutrient salts proved to be inversely correlated with zooplankton diversity and may led to changes within zooplankton community structure. The dominant species in 1985 (*Tintinnopsis lobiancoi* and *Acartia clausi*) were replaced by *Tintinnopsis tocantinensis* and *Oithona nana*. The first two species are denser than the second ones, this may indicate stressed situation and /or confined water. Moreover, 21 zooplankton species were found for the first time in the Lagoon. Few zooplankters occurred all over the whole area of the Lagoon, such as *Oithona nana*, *Centropages ponticus* and *Euterpina acutifrons* (Copepoda) and *Tintinnopsis tocantinensis* (Protozoa) as well as *Limacina inflata* (Pteropdoda), while others were highly confined to restricted areas.

The total mullet catches showed general negative trends in spite of general increase in fishing effort. It reached to 1,011 tons in 1994 contributing 67.3% of total Lagoon production. The percentage gradually decreased to 43.9 % in 1995 and 32.9 % in 1999. The production of the most economic important fish species (*Sparus aurata*) sharply decreased from 1,105 ton in 1962-1966 to 252 and 223 tons during 2000 and 2001, respectively (El-Ganainy & Yassien 2002). The changes in zooplankton community structure may be one of the main reasons.

7.5 SPECIES RICHNESS AND OTHER DIVERSITY INDICES

Regarding spatial distribution, the highest species number (40) was found at station II, while station XII had the lowest of 20 species. Stations II & VIII showed the highest evenness and diversity, 0.67 and 2.47, 2.36 & 0.84, 0.82 (Table 7. 3).Station VI sustained the lowest evenness and diversity values, 0.41 and 1.33 & .49, respectively. Cluster analysis of zooplankton measures revealed three groups, stations II, VIII; stations V, VI, XII and the other stations. The highest similarity (80.1) occurred between station IX and station X within the third group (Fig. 7. 21). On a seasonal basis, spring maintained the highest species number (42 species), while autumn had the lowest (31 species).The highest evenness and diversity, 0.7, 2.6 & 0.86 were recorded in winter, while the lowest, 0.47, 1.73 & 0.69 occurred in summer (Table 7. 4). Canonical corresponding analysis (CCA) was used to summarize the relationships between the most common zooplankton groups or species (Figs 7. 22, A&B) and environmental variables. CCA revealed that salinity, water temperature and ammonium were the most important factors affecting zooplankton structure in Bardawil Lagoon. The ordination by dominant groups shows a negative correlation between Rotifera , Protozoa and water temperature, ammonia and salinity. Pteropoda was highly associated with total phosphorus and dissolves oxygen, while Copepoda seem to withstand all of abiotic variables. The ordination by dominant species was more informative. *Tintinnopsis tocantinensis*, *Synchaeta calva*, *Acartia clausii* and *Favella serrata* were negatively correlated with most of abiotic factors, salinity, water temperature, ammonia and biological oxygen demand, in particular. *Oithona nana* and *Centropages ponticus* were highly associated with salinity and dissolved oxygen, respectively.

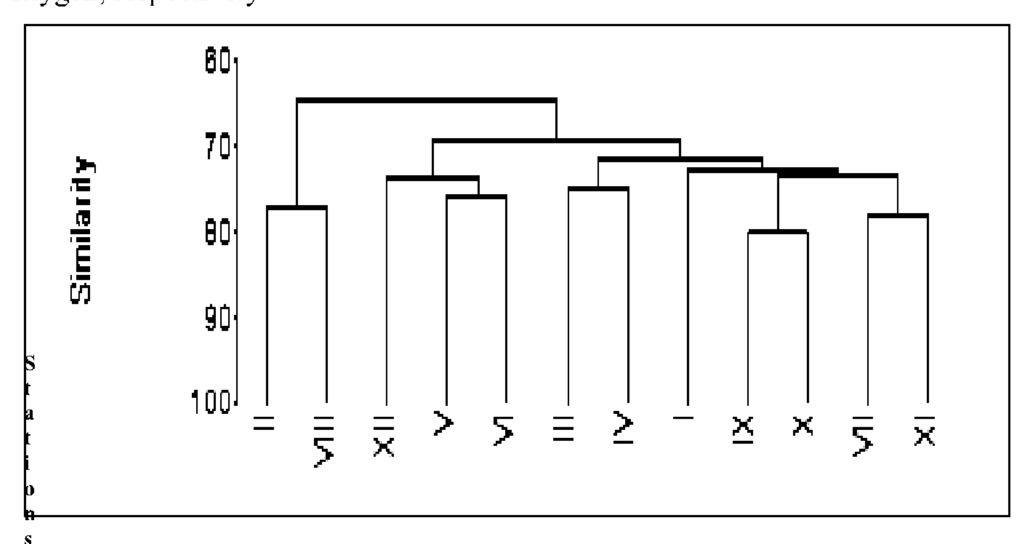


Fig. 7.21. **Clustering of the selected stations according to their zooplankton fauna**

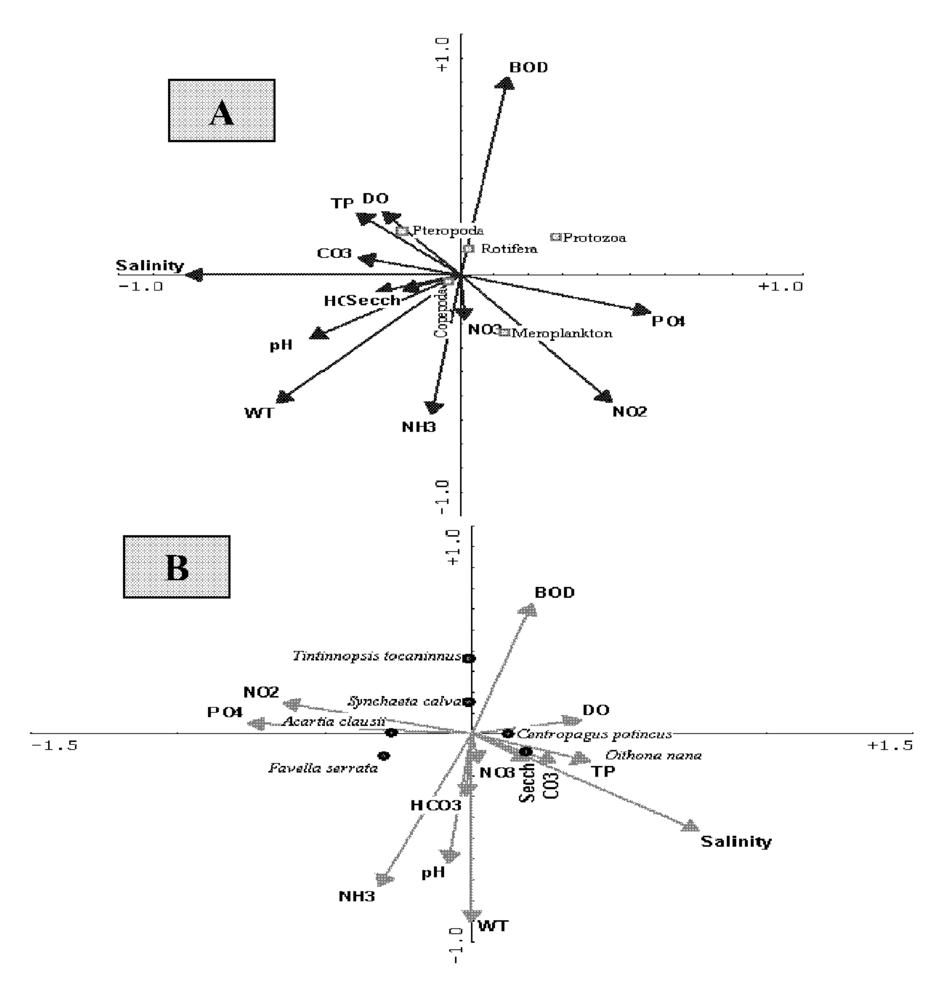


Fig. 7.22. CCA ordination plot of axis I and axis II relating variations in the distribution of zooplankton groups or species to environmental variables. The joint plot of groups A (quadrate) and species B (circle), and the environmental arrows is a biplot that approximate the weighted average of each group or species with respect to each of the environmental variables. The abbreviations used for physical &chemical variables are: WT=Water temperature, NH3=Ammonium, HCO3=Bicarbonate, CO3=Carbonate, Secch= Secchi-depth, NO3= Nitrate, NO2=Nitrite, DO=Dissolved Oxygen, BOD=Biological Oxygen Demand, PO4= Orthophosphate and TP= Total phosphorus

Table 7. 3. Diversity indices of the zooplankton (spatial distribution)

Species	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
	31	40	29	36	27	26	31	33	31	29	30	20
Richness	2.60	3.35	2.44	3.00	2.28	2.22	2.57	2.72	2.59	2.37	2.48	1.70
Evenness	0.55	0.67	0.60	0.56	0.49	0.41	0.47	0.67	0.50	0.57	0.51	0.45
Shannon diversity	1.90	2.47	2.01	2.01	1.60	1.33	1.62	2.36	1.72	1.92	1.72	1.35
Simpson diversity	0.66	0.84	0.78	0.76	0.60	0.49	0.61	0.82	0.64	0.72	0.67	0.55

Table 7. 4. **Diversity indices of the zooplankton (seasonal)**

Species	Winter	Spring	Summer	Autumn
	41	42	37	31
Richness	3.65	3.47	3.30	2.78
Evenness	0.70	0.47	0.47	0.55
Shannon diversity index	2.60	1.74	1.73	1.89
Simpson diversity index	0.86	0.62	0.69	0.73

7.6 SUMMARY

A total of 58 zooplankton species were recorded from 12 sampling sites in Bardawil Lagoon during 2002 – 2003. Copepoda was the most abundant group, contributing 69.9 % of total zooplankton density. Zooplankton reached the highest density at station X during summer (198,500 ind. m^{-3}). Protists (23 species), made up 10.3 % of total zooplankton. Winter was characterized by the highest standing crop. The dominant and common zooplankton species in 1985; mainly *Tintinnopsis labiancoi* (Ciliophora) and *Acartia clausii* (Copepoda) were replaced by *T. tocantinensis* (Ciliophora) and *Oithona nana* (Copepoda). 21 zooplankton species were newly recorded in the Lake. A few species occurred all-over the whole Lagoon; *Oithona nana*, *Centropages ponticus* and *Euterpina acutifrons* (Copepoda), *Tintinnopsis tocantinensis* (Ciliophora) and *Limacina inflata* (Pteropoda), while the others were confined to restricted areas.

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7.8 PLATES OF ZOOPLANKTON (7.1-7.12)

(Photos of El-Shabrawy, http://www. Google.image, http:/www.ibss.iuf.net/copepoda/cal12.html http://www.cooa.unh.edu/webcoast/images/zooplankton, http://www.home. Hiroshima-u.ac.jp)

Plate 7.1
Paracalanus parvus

Plates 7.2
Paracartia latisetosa

Plates 7.3
Acartia clausi

Plates 7.4
Centropages ponticus
Calanus finmarchisus

Plates 7.5

Oithona nana

Plates 7.6

Euterpina acutifrons
Microsetella norvegica
Harpacticus sp.

Plates 7.7
Evadne spinifera
Podon polyphemoides

Plates 7.8

Sagitta setosa
Oikopleura longicauda

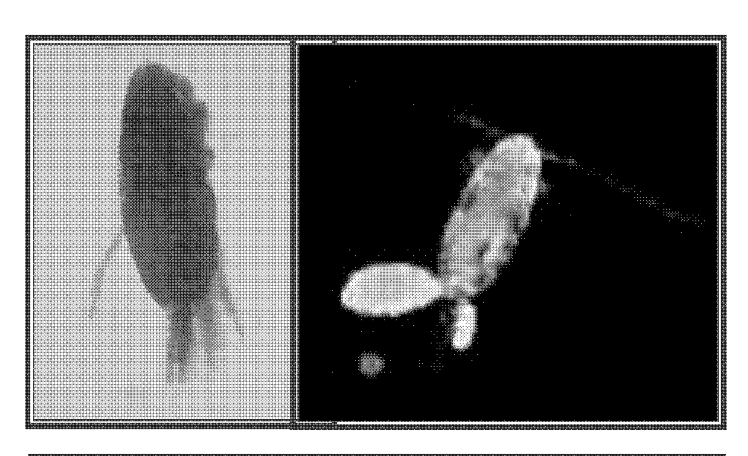
Plates 7.9
Leprotintinnus bottnicus
Undella sp.
Favella serrata
Favella ehrenbergi

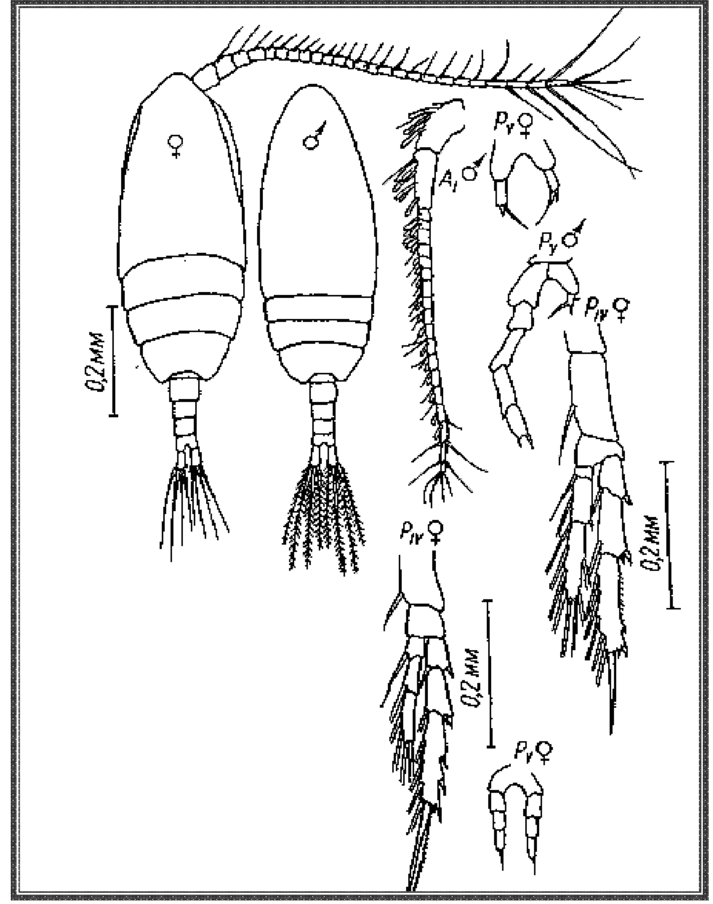
Plates 7.10
Ptychocylis sp.
Dictyocysta elegans
Metacylis sp.

Plates 7.11
Helicostomella subulata
Tintinnopsis campanula

Plates 7.12
Bivalvia larva
Synchaeta calva
Limacina inflate
Metanauplius larva
Cirripedia larva
Obelia medusa
Polycheate larva

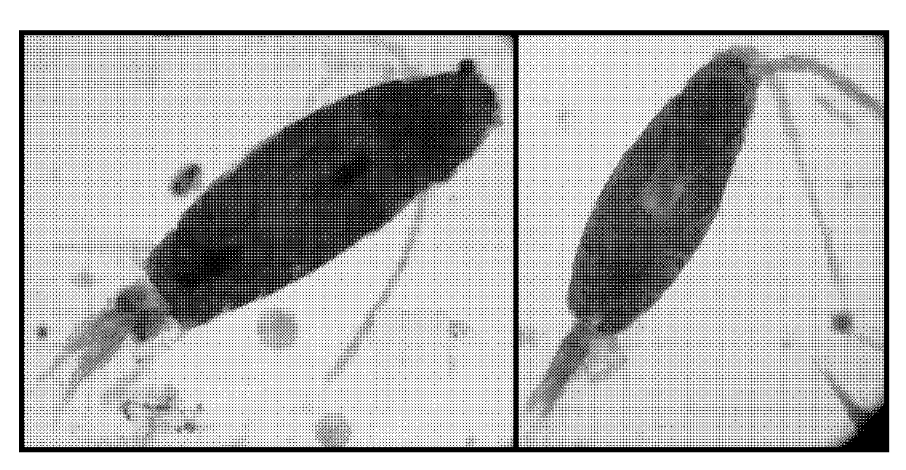
Plate 7. 1

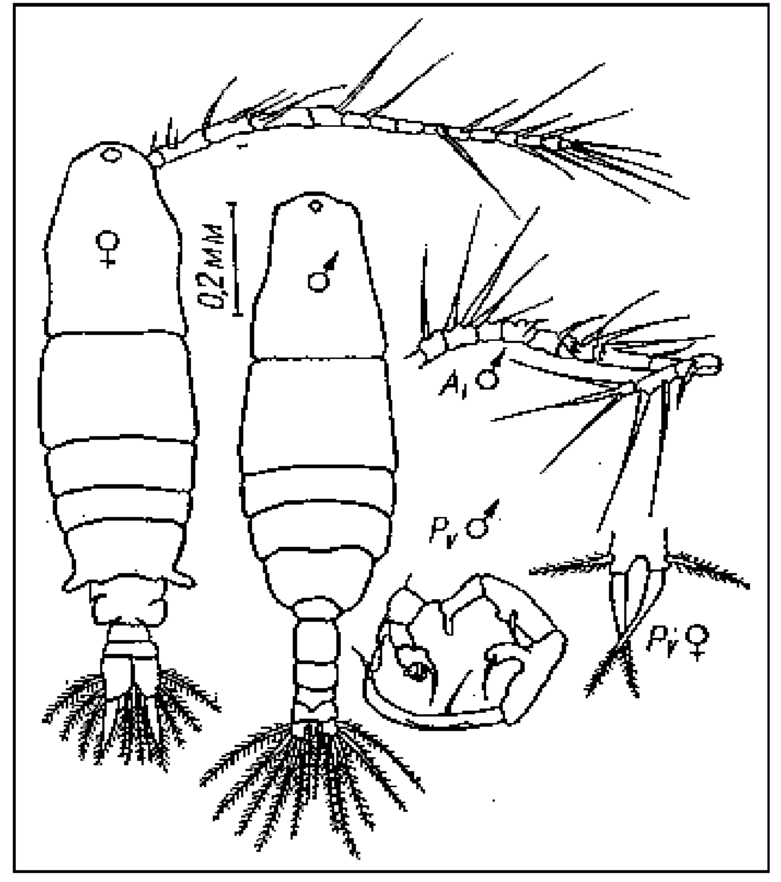




Paracalanus parvus

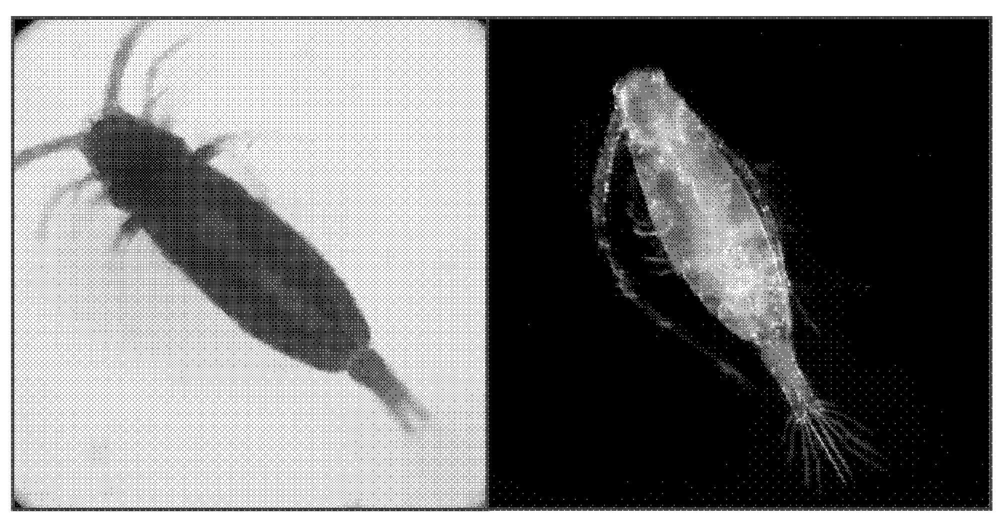
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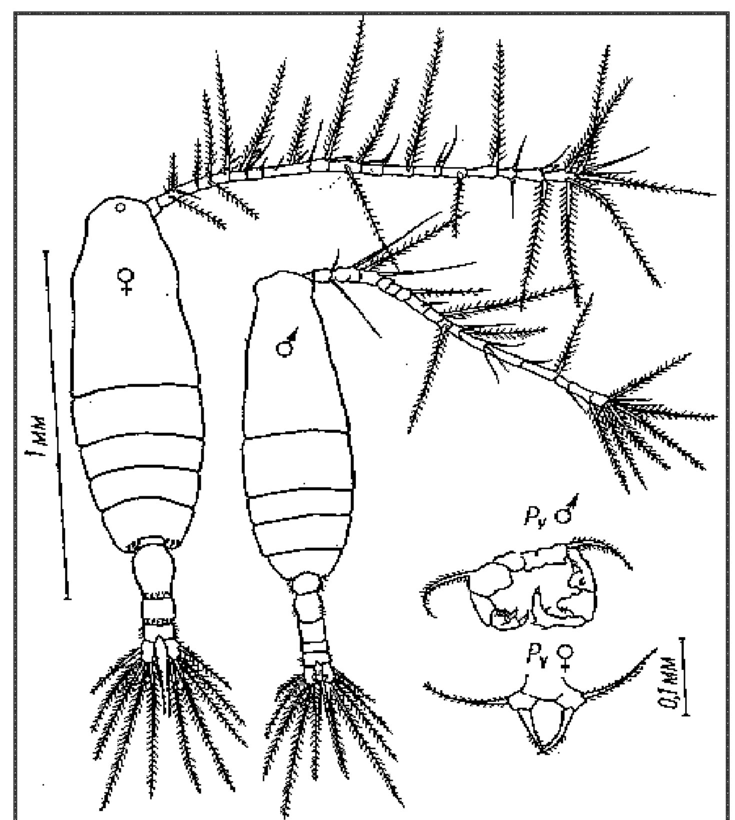




Paracartia latisetosa

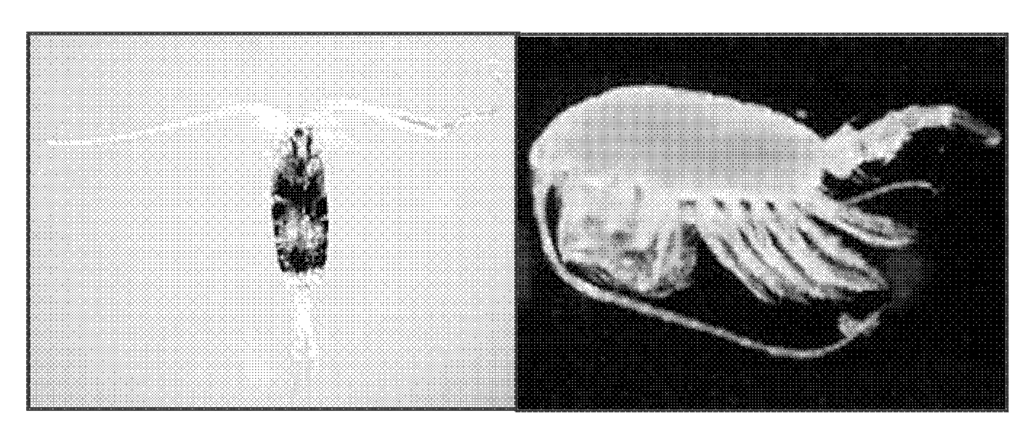
Plate 7. 3



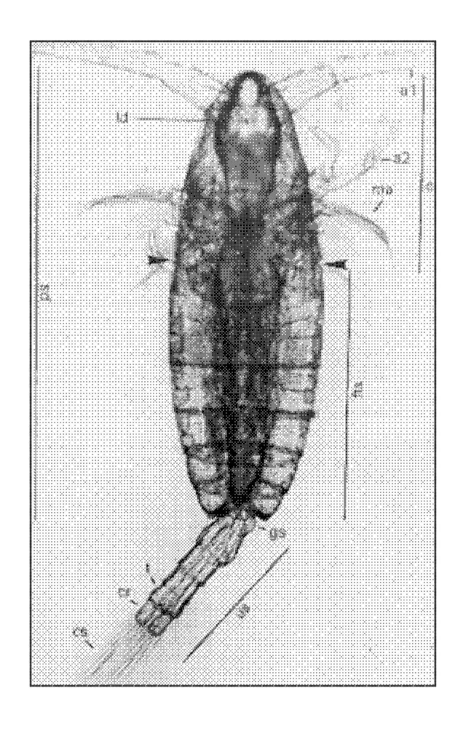


Acartia clausi

Plate 7. 4

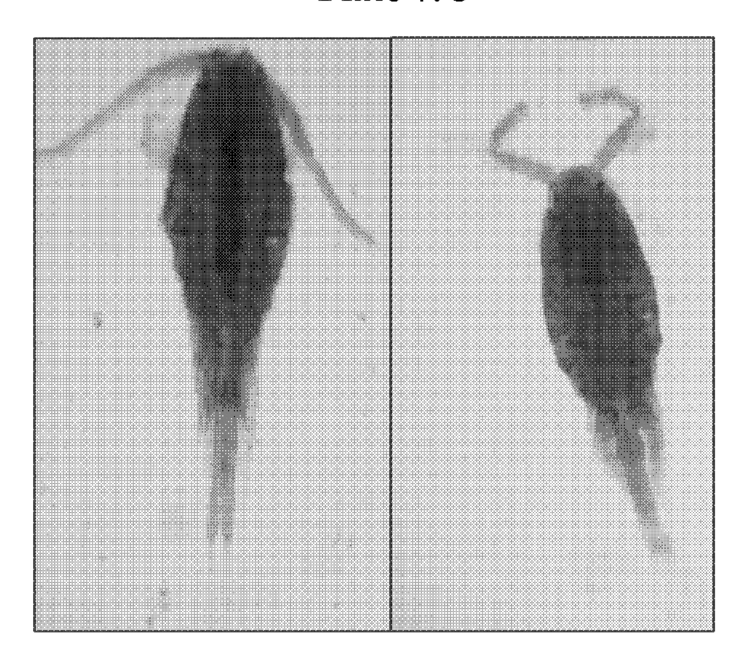


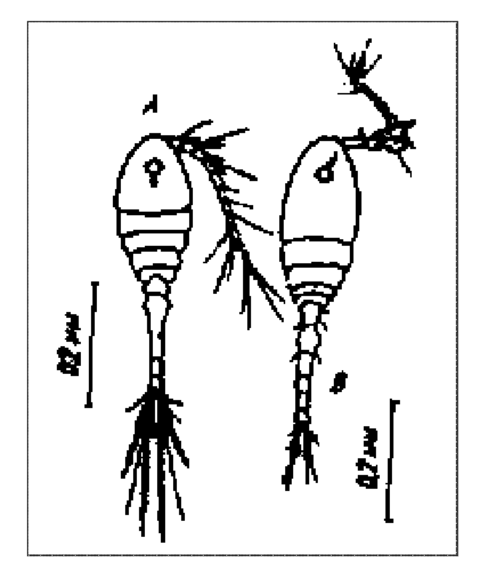
Centropages ponticus



Calanus finmarchisus

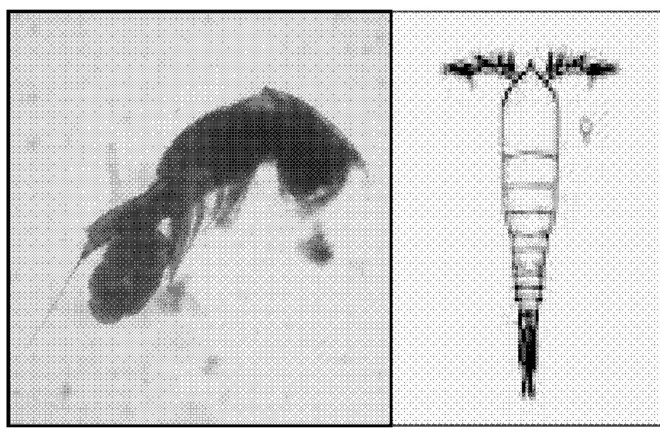
Plate 7. 5



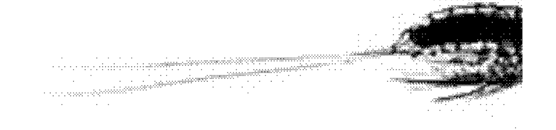


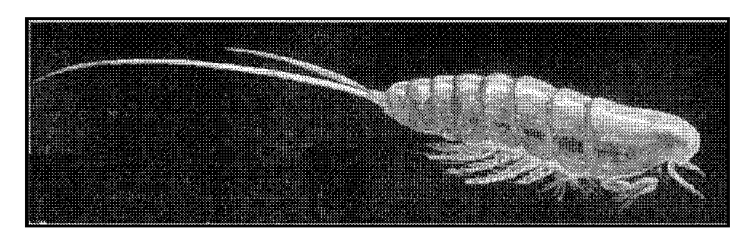
Oithona nana

Plate 7. 6

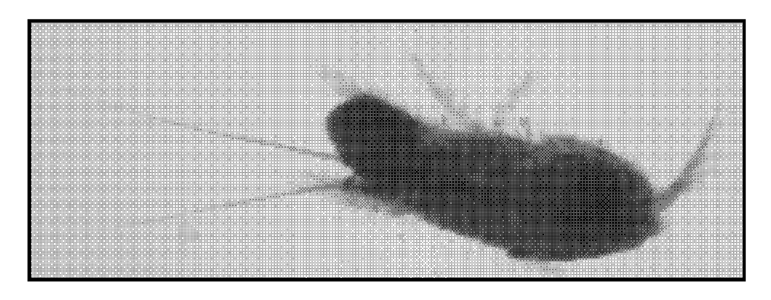


Euterpina acutifrons



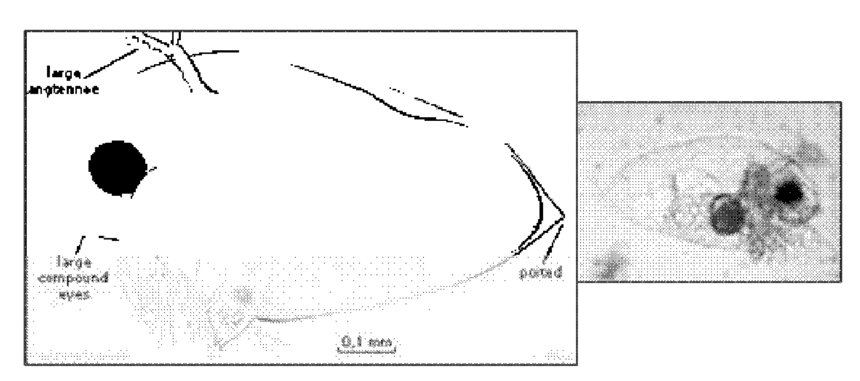


Microsetella norvegica

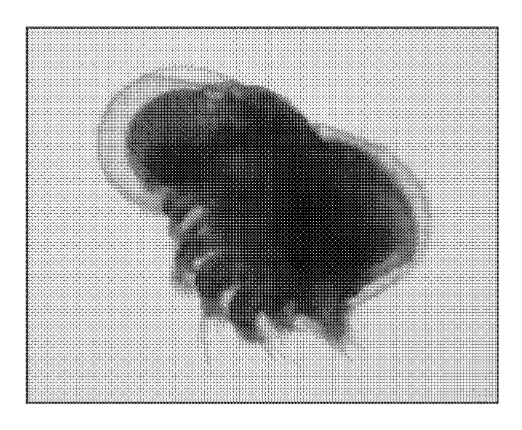


Harpacticus sp.

Plate 7. 7

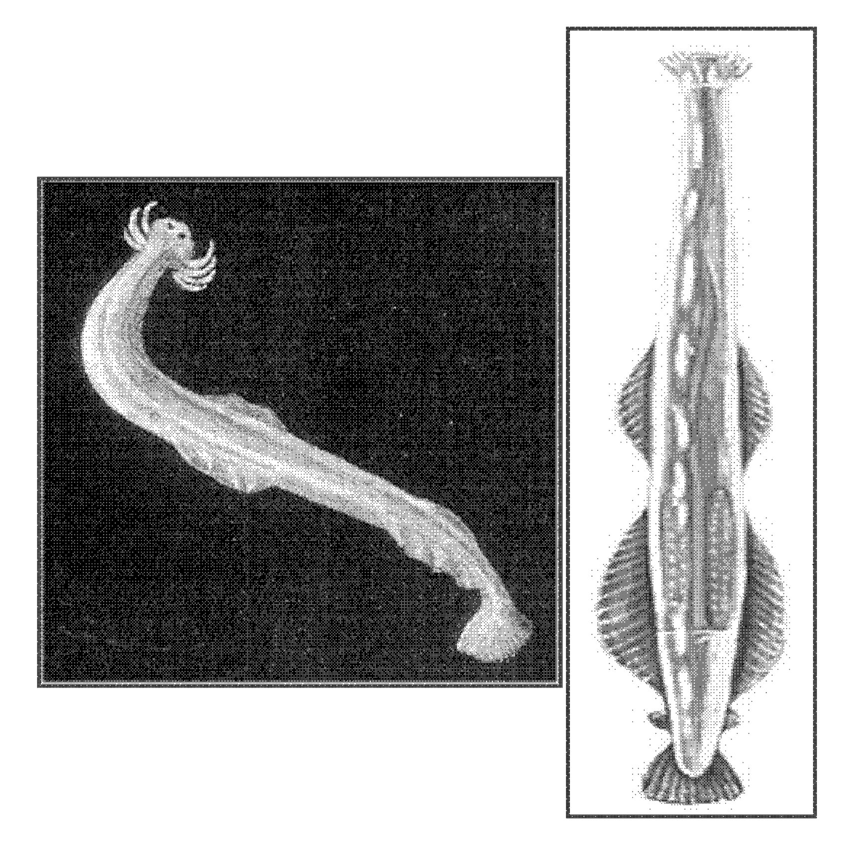


Evadne spinifera



Podon polyphemoides

Plate 7. 8

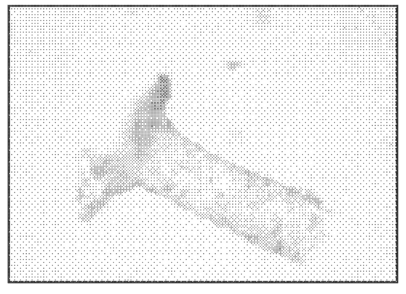


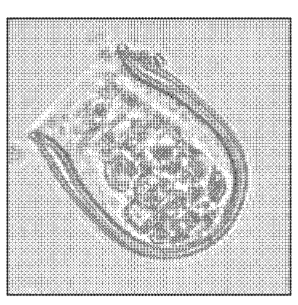
Sagitta setosa

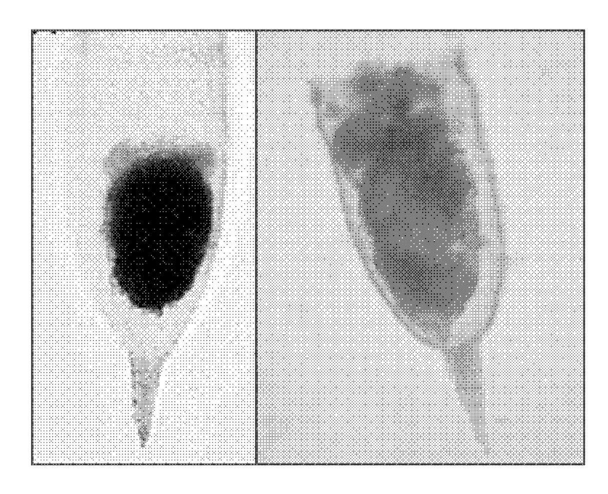


Oikopleura longicauda

Plate 7. 9


Leprotintinnus bottnicus


***Undella* sp.**


Favella serrata

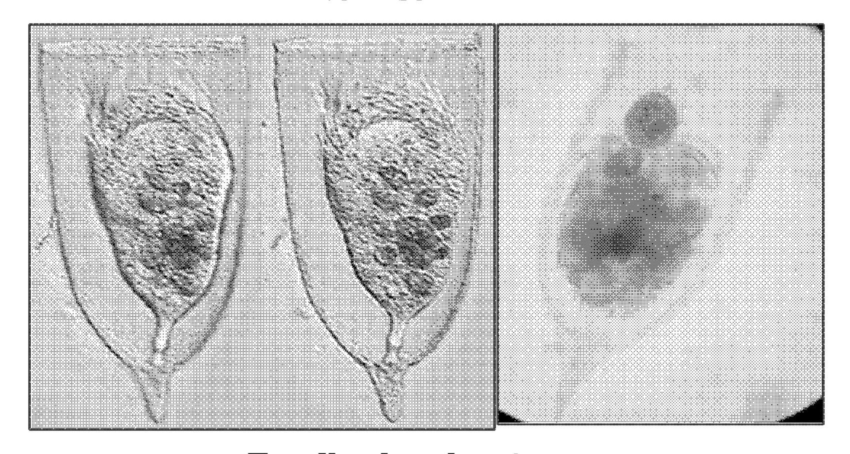
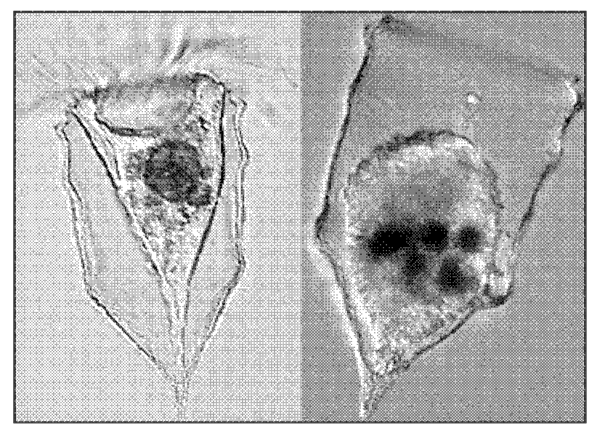
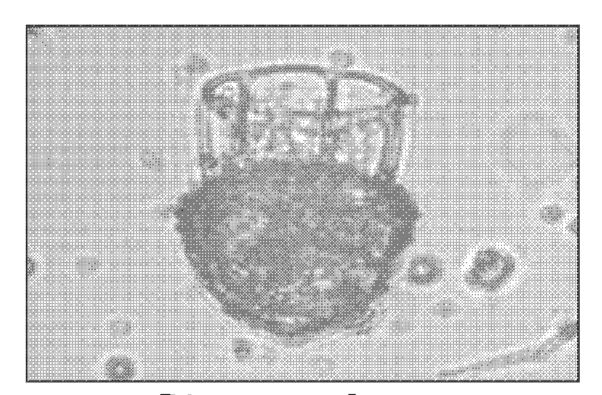

Favella ehrenbergi

Plate 7. 10



***Ptychocylis* sp.**

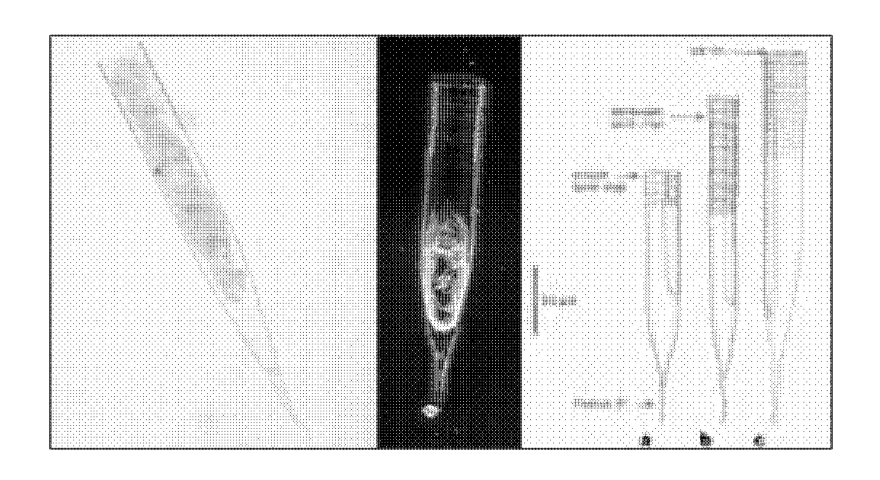


Dictyocysta elegans

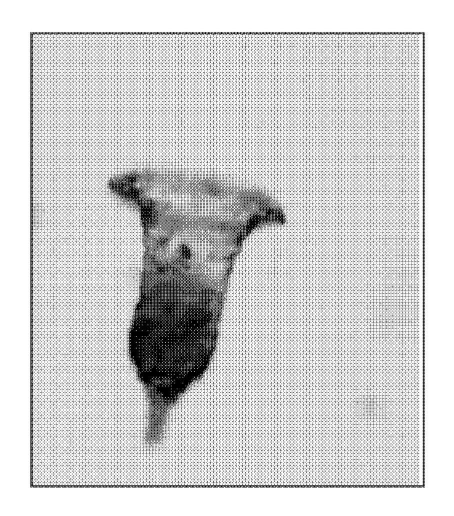


***Metacylis* sp.**

Plate 7. 11



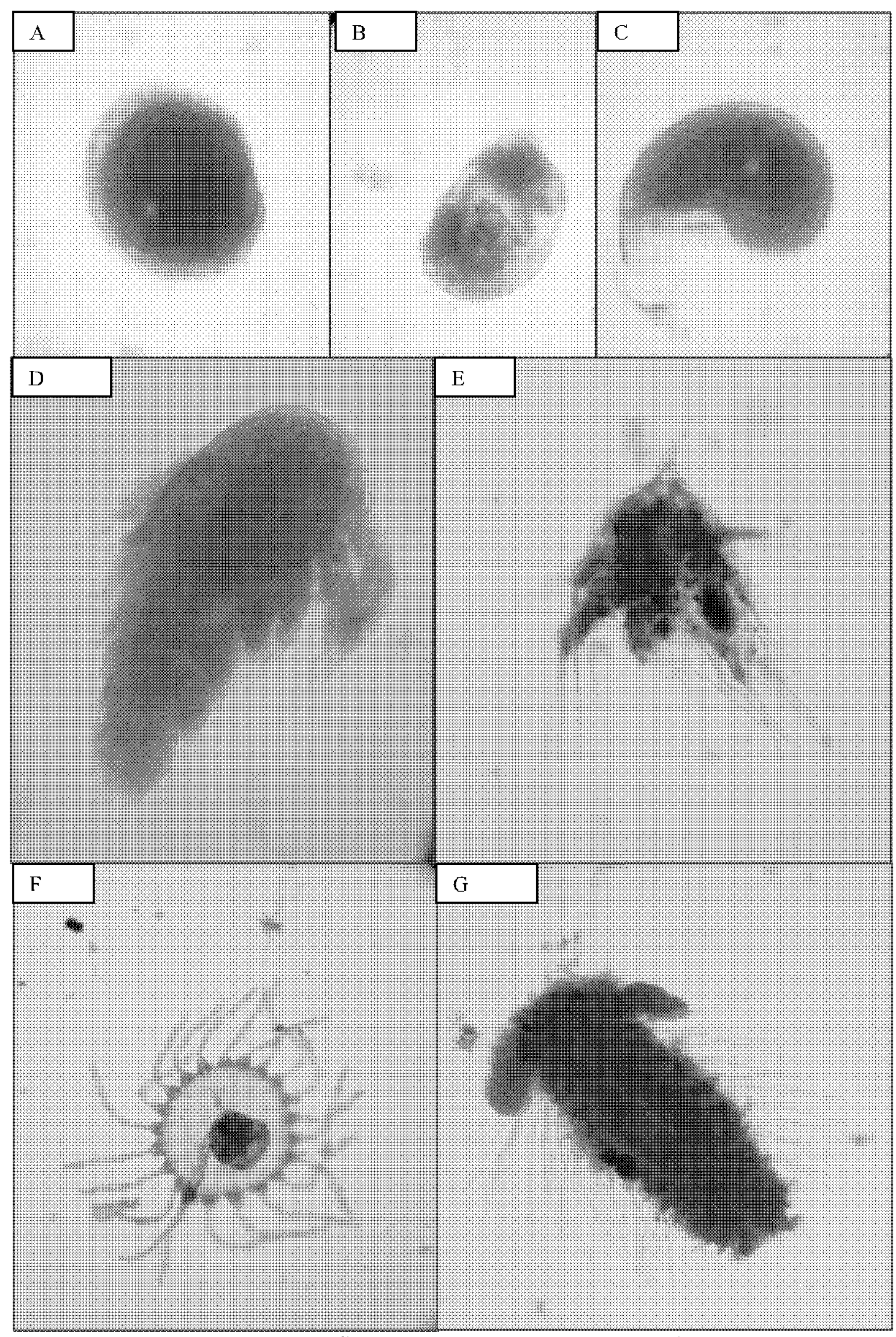
Helicostomella subulata



Tintinnopsis campanula



Plate 7. 12



A-Bivalvia larva **B- *Synchaeta calva*** **C- *Limacina inflata***
D-Metanauplius larva **E- Cirripedia larva** **F- *Obelia* medusa**
G- Polycheate larva

Chapter 8
Benthic Invertebrates

The benthic invertebrates in aquatic ecosystems play an important role in the transformation of the organic matter sediment on the bottom to its base elements and subsequently contribute to the basic nutrition of fish. The composition of the benthic fauna has largely been considered as a good indicator of water quality because, unlike planktonic species, they form relatively stable communities in the sediments which do not change over long time intervals and reflect characteristics of both sediments and upper water layer.

8.1 MEIOBENTHOS

Meiofauna (meiobenthos) includes small benthic animals with phylogenetic representation from almost all invertebrate phyla. They are regularly defined as those benthic metazoans passing thru 500 µm sieves but retained on meshes of 40–64 µm (Higgins & Thiel 1988). Meiofauna is not a homogeneous ecological group; but occupies a variety of habitats from Alpine lakes to deep-sea trenches. Meiobenthos comprises a ubiquitous, taxonomically diverse group with numerous components of the fauna of marine sediments (Coull 1999) with a fast turnover, producing several generations a year. These animals facilitate remineralization of organic material and enhance bacterial activity (Tietjen 1980). They are also important food for higher trophic levels (Gee 1989, Castel 1992). Meiobenthos are sensitive to anthropogenic disturbance and pollution (Coull & Chandler 1992, Warwick 1993, Mirto *et al.* 2002) and their potential as indicators of environmental condition is widely recognized (Moore & Bett 1989, Kennedy & Jacoby 1999, Schratzberger *et al.* 2000). A number of studies have shown that their abundance and taxonomic diversity tend to decrease under conditions of great physical and chemical variability (Tietjen 1991, Coull 1999).

In Egyptian lakes, very little is known about the meiofauna, except the works of Fishar (1999a) in Lake Manzala, Fishar (2000) in Lake Qarun and Fishar & Abdel Gawad (2004) in Wadi El- Raiyan Lakes. The work of Fishar (2005a) is the first so far to deal with this important component in Lake

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Mohamed R. A. Fishar

Bardawil, except recording of some meiobenthic organisms during the studies of Aboul-Ezz (1988) and Abdel-Malek *et al.* (1993) on macrobenthic community.

Fishar (2005 a) studied meiobenthic fauna of Lake Bardawil during 2004. He selected 12 sites representing different habitats of the Lake, six stations from the eastern side and six from the western one (Fig. 8.1).

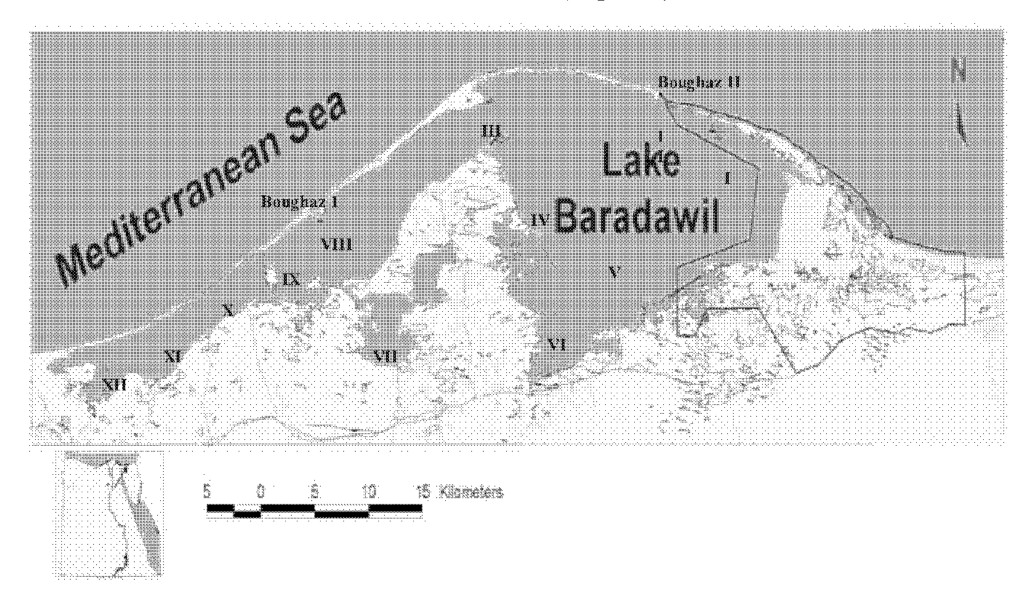


Fig. 8.1. **Map showing the sampling locations in Lake Bardawil (Fishar 2005a&b)**

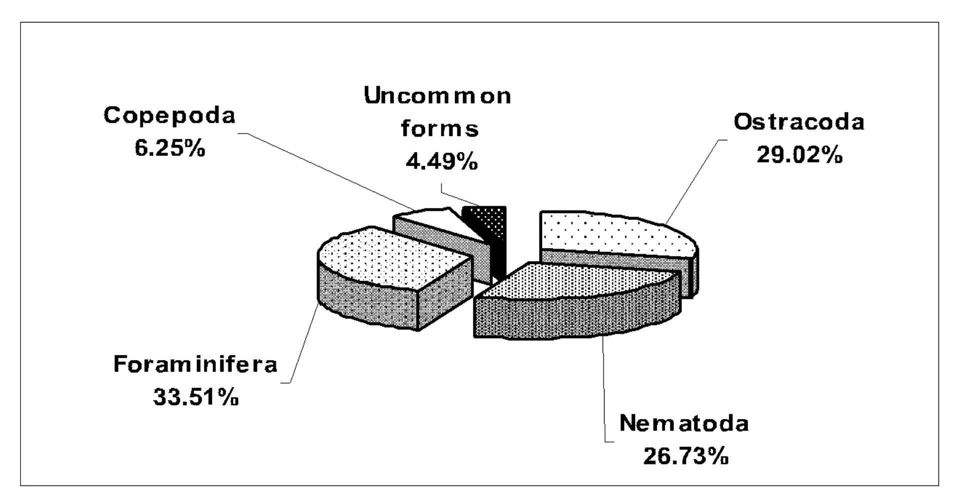


Fig. 8.2. **Percentage composition of meiofauna in Lake Bardawil (Fishar 2005a)**

8.1.1 Species Composition

Free living Foraminifera, Ostracoda and Nematoda were found to be the main groups of meiofauna in the lake. The meiobenthic species are listed in Table (8.1). Numerically, they were represented by 33.51%, 29.02 % and 26.73% of the total number of meiofauna in the area, respectively (Fig.8.2). Individuals of Copepoda (6.25%) appeared in the area followed by very few individuals of different meiobenthic forms (Tubificidae, Tardigrada, Nemertina, Crustacea, Mollusca and Gnathostomulida).

***Table 8.1.* Check list of meiobenthic fauna collected from Lake Bardawil (after Fishar 2005a)**

Group	Species
Foraminifera	*Elphidium* sp. *Ammonia* sp. *Quinqueloculina* sp. *Trochammina* sp.
Nematoda	*Thormella teres* *Rhabditis marina* *Enoplus meridionalis*
Polychaeta	Larvae of Polychaeta *Polydora ciliate*
Oligochaeta	*Enchytraeus adriaticus*
Nemertinea	Nemertina sp.
Ostracoda	*Cyprideis torosa* *Aglaiocypris* sp.
Copepoda	*Euterpina acutifrons* *Harpacticus* sp. Cyclopoid copepoda Nauplius larvae
Mollusca	*Lanthina communis*
Tardigrada	Tardigrad sp.
Gnathostomulida	*Austrognathda* sp.

8.1.2 Spatial and Temporal Distribution of Total Meiofauna

The average density of total meiofauna in the whole area during the period of study is 319 organisms /10 cm^2. This value is lower than that recorded in some Egyptian lakes; where 1495 individuals/10 cm^2 were found in Lake Manzala (Fishar 1999); 609 individuals/10 cm^2 in Lake Qarun (Fishar 2000) but higher than that recorded in the upper and lower Wadi El Raiyan lakes (Fishar & Abdel Gawad 2004). As shown in Fig. 8.3, three peaks were recorded in the area; the highest (502 organisms /10 cm^2) was observed in the east (station 3), and the second and third ones (458 and 452 organisms /10cm^2) were observed in middle and west (stations 6 and 12, respectively).

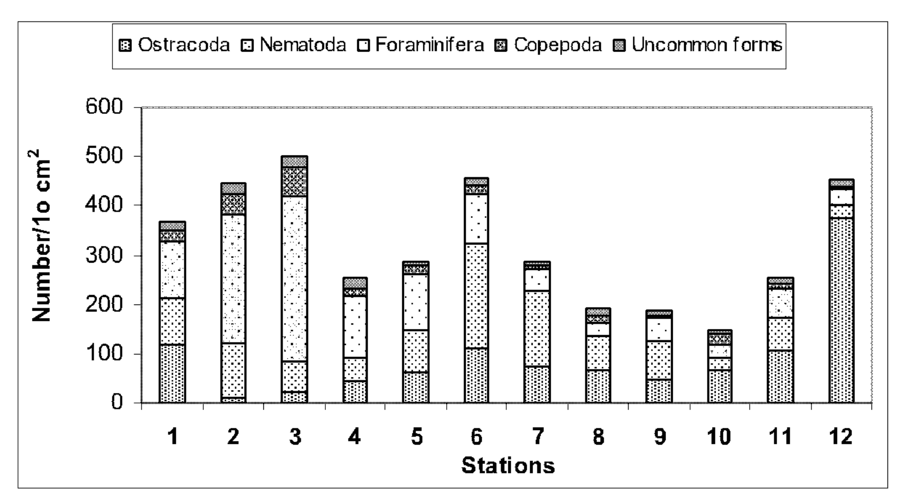


Fig. 8.3. **Distribution of different meiobenthic groups in Lake Bardawil (Fishar 2005a).**

The meiobenthos were most abundant and diverse in sandy sediments. Fishar (2005a) noted the positive correlations between gravel grain-size, and diversity as well as number of meiobenthos. He stated also that meiofaunal abundance is known to be correlated with organic carbon content. There always appears to be sufficient organic matter for the resident meiofauna. Study results of 2004 indicate that high densities of meiofauna were related with high contents of organic matter.

Tidal movement of water may scour sediments, removing fine material from inlets and establishing a gradient of decreasing particle-size with increasing distance from the sea. Such movements of water may also be important in dispersal of meiobenthos (Armonies 1994). Meiobenthos were less diverse in the inlets of the lake and there was evidence of greater spatial variability, which may be a consequence of disturbance caused by artificial inlets. The results indicate that station 4 (in eastern part of lake) and station 10 (in western part) have a relatively low density of organisms compared with other localities.

Regarding temporal distribution of meiofauna, the highest value was recorded during January. This is attributed to the abundance of food supply (benthic primary productivity) rather than high reproductive and development rates. A remarkable decrease was recorded during next months (except relative increase during July and August); minimum values were recorded during November (Fig. 8.4).

8.1.3 Spatial and Temporal Distribution of the Recorded Taxa

8.1.3.1 Foraminifera

As shown in Fig. 8.5, Foraminifera species were numerically high at eastern stations 2 and 3, where 260 and 235 organisms /10 cm^2 were recorded,

respectively. At the same time, the lowest density was recorded at western stations 8, 10 & 12, where 47, 26 & 35 organisms /10 cm^2 were recorded, respectively. Regarding monthly variations, Foraminifera fluctuated from month to another. The highest value (181 organisms /10 cm^2) was recorded during January, while the lowest (50 organisms /10 cm^2) was recorded during September (Fig 8.6). Foraminifera group was represented by four different species namely: *Elphidium* sp., *Trochammina* sp., *Ammonia* sp. and *Qunqueloculina* sp.

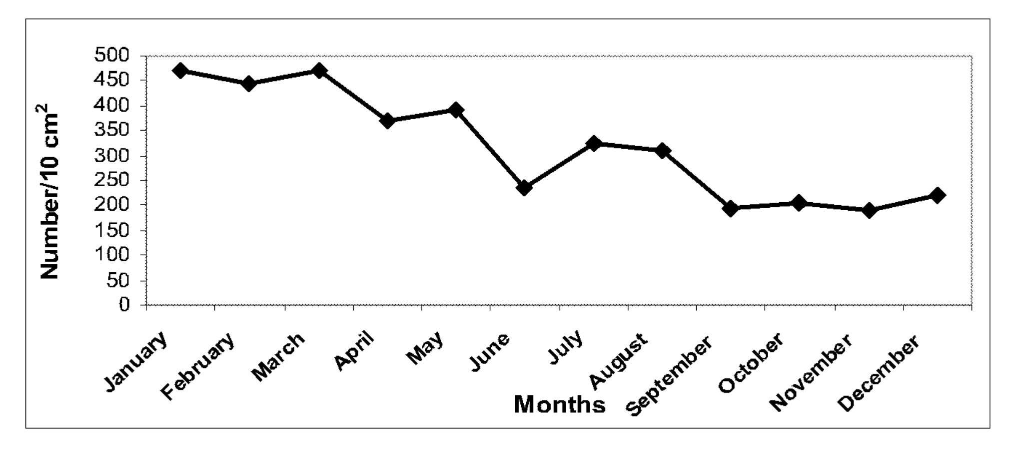


Fig. 8. 4. **Monthly variations of total meiobenthos in Lake Bardawil during 2004 (Fishar 2005a)**

8.1.3.2 Ostracoda

The average density of Ostracoda for the whole area during 2004 was 93 organisms /10cm^2. The average standing crop fluctuated between 12 organisms /10cm^2 in station 2 and 356 organisms /10cm^2 in station 12 (Fig. 8.5).

Concerning the temporal distribution of average ostracod's crop in the whole area of investigation, two peaks were observed. A higher one (169 organisms /10cm^2) appeared in July and a low one (149 organisms /10cm^2) appeared in January. The minimum density (47 organisms /10cm^2) was estimated during June (Fig. 8.6). Ostracoda group was represented by two species namely *Cyprideis torosa* and *Aglaiocypris* sp.

8.1.3.3 Nematoda

The average density of Nematoda for the whole area during 2004 was 85 organisms /10cm^2. The middle stations (6 & 7) were the most favorable grounds for nematodes in the area, where density of 213 and 155 organisms /10cm^2 were recorded, respectively (Fig. 8.5).The minimum value of density was found at stations 10 and 12 with the same values (23 organisms /10 cm^2).

As regards temporal variation, two high values (225 & 222 organisms /10 cm^2) were recorded during February and March, while in the next months, the density decreased gradually to reach minimum values during November and

December (Fig. 8.6). Nematoda was represented by three species namely: *Thormella teres*, *Rhabditis marina* and *Enoplus meridionalis*.

8.1.3.4 Copepoda

The spatial distribution of Copepoda ranged from 58 organisms /10 cm^2 at station 3 to 3 organisms /10 cm^2 at station 12. The eastern part of the lake is more productive than the western one (Fig. 8.5).

The temporal distribution of average copepod crop in the whole area of investigation showed a peak of 169 organisms /10cm^2 in March. The minimum density (47 organisms /10cm^2) was noted in June (Fig. 8.6). They were composed mainly of three species that belong to two orders namely: Harpacticoida (*Euterpina acutifrons* and *Harpacticus* sp.) and Cyclopoida .

8.1.3.5 Uncommon forms

Small numbers of different forms of meiobenthos that belong to Polychaeta (larvae of Polychaeta species and *Polydora ciliate*), Oligochaeta (*Enchytraeus adriaticus*), Tardigrada, Mollusca (*Lanthina communis*), Nemertinea, Crustacea and Gnathostomulida (*Austrogmathda* sp.) were recorded. The average density of these species and larvae for the area during the period of study was 14 organisms /10 cm^2. The eastern stations (2, 3 & 4) were the most favorable grounds for these forms in the area, where similar values (23 organisms /10cm^2) were observed (Fig. 8.5).

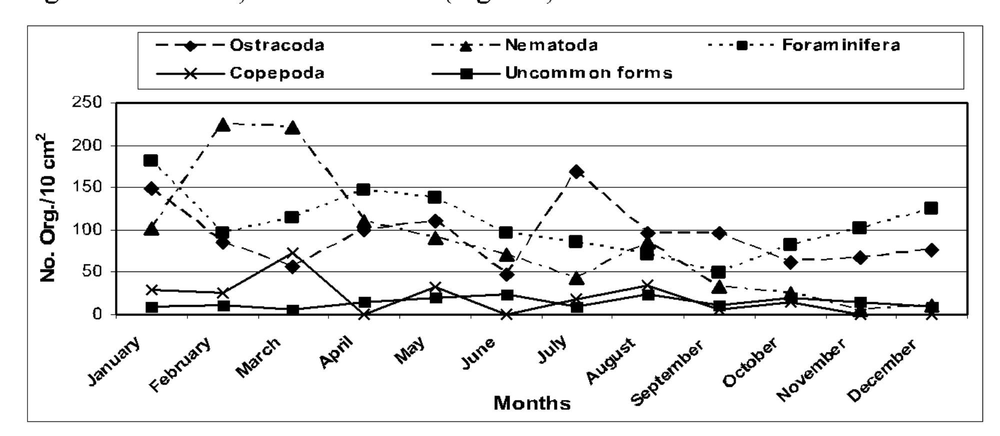


Fig.8.5. **Monthly variations of different meiobenthic groups in Lake Bardawil (Fishar 2005a)**

The reaction of different meiobenthic taxa to various environmental factors was different. Foraminifera showed a negative correlation with mud and a positive one with organic matter. Salinity affects positively the abundance of ostracods. Benthic copepods appear to be the major meiofauna prey item for most predators of meiofauna (Gee 1989, Coull 1990, Feller & Coull 1995). Additionally, these copepod preys primarily live in muddy sediments (Smith &

Coull 1987) or on plants (Sogard 1984, Gibbons 1988). In mud, the fauna is restricted to the upper few mm to cm of oxidized sediment, where predators only need to take a shallow bite to get food. In sand, the fauna is distributed deeper and not as readily available to predators (Coull & Bell 1979, Hicks & Coull 1983). Fishar (2005a) confirmed the previous results in Lake Bardawil, where the major meiofaunal predators are juvenile fish, shrimp (prawns), and most removal of meiofauna takes place in muddy substrates or in areas with substantial seagrass. He observed a negative correlation between mud and copepods and positive correlation between gravel and copepods.

8.2 MACROBENTHOS

Macrobenthic invertebrates in Lakes are frequently used to evaluate the overall ecosystem "health" (Flint 1979, Reynoldson & Zarull 1989, Rosenberg & Resh 1993, Reynoldson *et al.* 1995) because these communities are important to material cycling and secondary production, and are sensitive to environmental contaminants. To fully understand the reasons of disturbances that affect benthic community and distribution, it is important to measure the environmental factors that provide the basic ecological template structuring the benthic community. The macroinvertebrates of coastal wetlands are important food resources and contribute to widespread use of wetlands as fish spawning (Jude & Pappas 1992) and waterfowl breeding areas (Prince & Flegel 1995). Despite the apparent importance of macroinvertebrates, comparatively little is known of their distribution and ecology in coastal wetlands in general (Krieger 1992).

The available data dealing with the macrobenthos in Lake Bardawil are scarce. Fouda *et al.* (1985) included macrobenthos in their study on ecology of Bardawil lagoon. They listed 30 species of benthic fauna and flora of the lake. Aboul-Ezz (1988) mentioned that the benthic community consists mainly of members of Annelida, Arthropoda and Mollusca. El-Shabrawy & Khalil (2003) studied the community structure, biodiversity, biomass and abundance of macrobenthos in the lagoon in relation to changes in some abiotic and biotic variables. Barbary & El-Shabrawy (2004) studied the community structure and biochemical parameters of annelid worms in the lake. They showed that biochemical parameters were higher in all studied specimens, during March owing to maturation of gametes and reproductive activities. El-Shabrawy & Rizk (2005) studied the long-term changes of Arthropoda and Mollusca. They observed dramatic changes in Arthropoda and Mollusca assemblages. Fishar (2005b) carried out the latest study on macrobenthos of the lake. He surveyed a monthly sampling of macroinvertebrates from 12 sites during 2004 (Fig. 8.1).

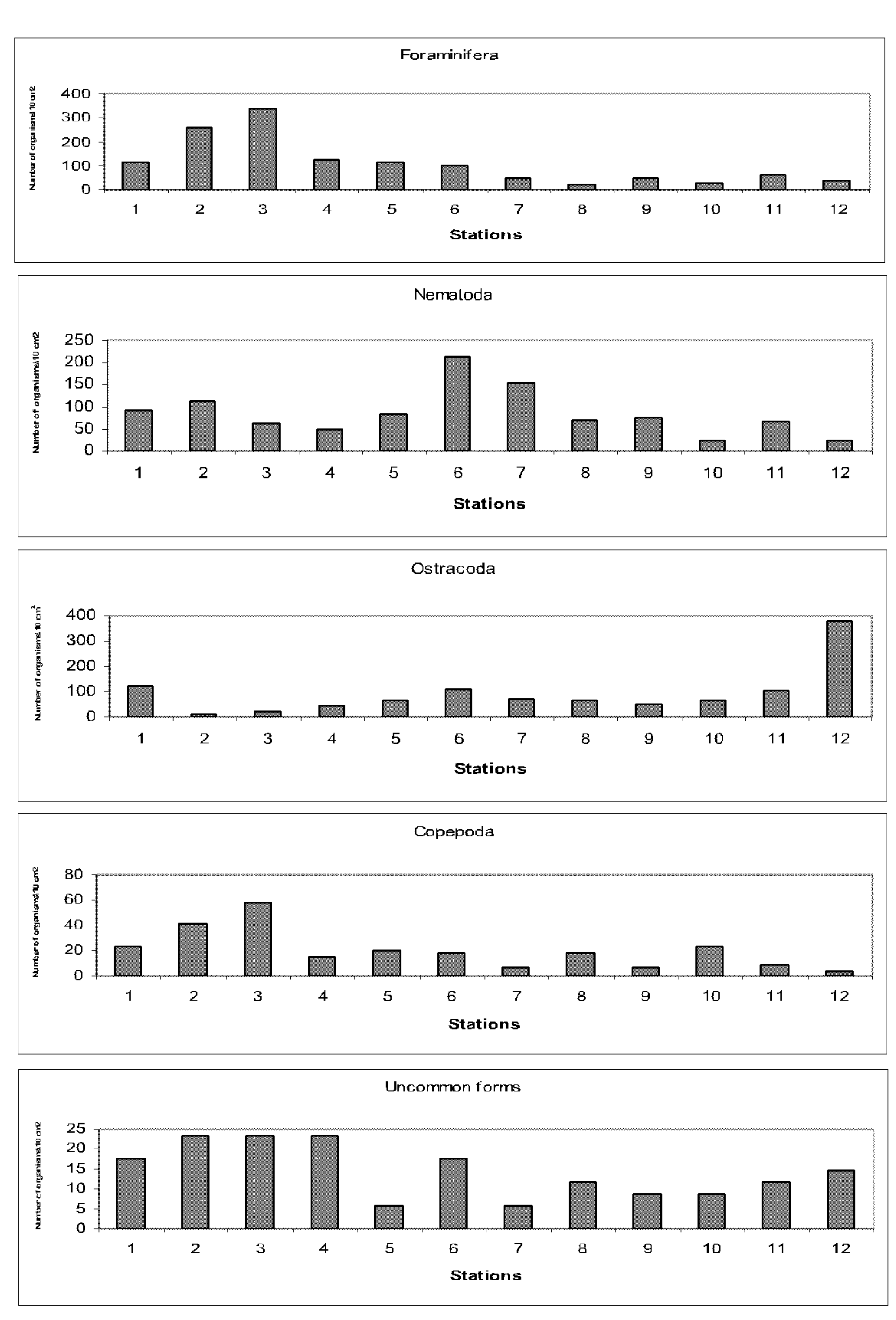


Fig. 8.6. **Distribution of different meiobenthic groups in the Lake Bardawil (Fishar 2005a)**

8.2.1 Community Composition and Relative Abundance

The annual average density of macrobenthic community recorded by Fishar (2005b) in Lake Bardawil was 359 organisms/m². This value is lower than that recorded in Lake Manzala (Fishar 1999_b & 2004), Lake Nasser (Fishar 1999_c) and Lake Qarun (Fishar 1993).

A total of 52 species of living bottom invertebrates were identified in the collected benthic samples during 2004. Of these, 19 arthropods, 16 molluscs, 14 annelids, 2 echinoderms, and one species of Coelenterata were recorded. The species are listed in Table 8.2. Mollusca occupied the highest population density (P.D.) of total macrobenthic fauna as represented by 60.79% followed by Annelida (24.05%) and then Arthropoda (14%) of the total number of macrofauna in the lake (Fig. 8.7). Individuals of Echinodermata and Coelenterata appeared in the lake with low numbers representing 1.01% and 0.15% of the total macrobenthos, respectively.

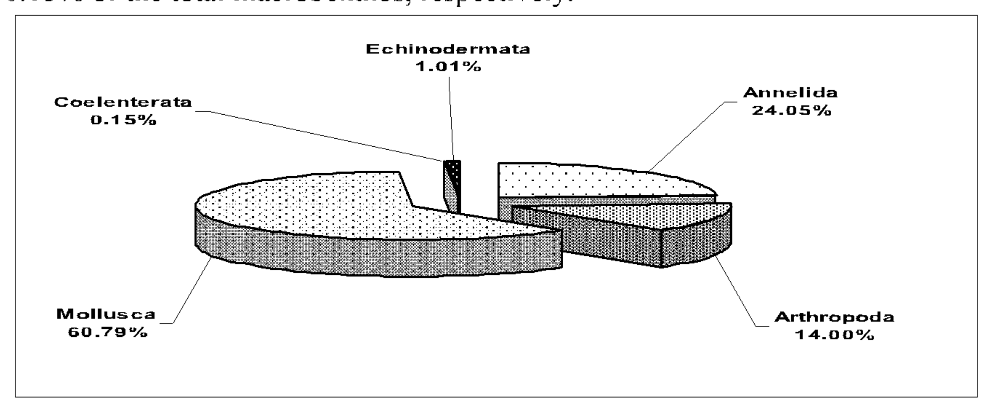


Fig. 8.7. **Percentage composition of macrofaunal community in Lake Bardawil (Fishar 2005b)**

Table 8.2. **Abundance of macrozoobenthic species in Lake Bardawil in different years (after Fishar 2005b)**

Group	Sampling year	1984	1986/87	2002/03	2004
	Species	Fouda *et al.* (1985)	Aboul – Ezz (1988)	El-Shabrawy & Khalil (2003)	Fishar (2005b)
Coelenterata	*Rhizostoma pulmo*		+		+
	Actinia equine			+	
Nematoda	*Thornella teres*	+			
	Rhabditis marina	+			
	Enoplus meridionalis		+		
Nemartinea	*Cerebratulus fuscus*			+	
Annelida	**Oligochaeta**				
	Tubificidae sp.			+	
	Polychaeta				
	Nereis pelagica	+		+	+
	Nereis diversicolor		+		
	Lumbriconereis fimchalenais			+	+
	Heteronereis sp.		+		
	Cirratulus cirratus			+	+
	Ophelia sp.			+	
	Hydroides elegans			+	+

Group	Sampling year	1984	1986/87	2002/03	2004
	Species	**Fouda** *et al.* **(1985)**	**Aboul – Ezz (1988)**	**El-Shabrawy & Khalil (2003)**	**Fishar (2005b)**
	Amphitrite affinis			+	+
	Syllis variegata			+	+
	Myxicola infundibulum			+	+
	Polydora ciliate			+	+
	Polydora sp.			+	
	Augeneriella bagunaria	+			
	Polychaet spp.			+	
	Spirorbis borealis	+		+	+
	Filograna implexa	+		+	+
	Hydroides norvegica		+		
	Sabella fabricia		+		
	Glycera rouxii		+		
	Capetella capitata		+		+
	Polygordius lacteus		+		
	Eupolymnia nebulosa		+		+
	Raphidrilus sp.		+		
	Dadecacera sp.		+		
	Cucumaria pseudocurata		+		
	Acmotryama autegaster		+		
	Eunica torquata		+		+
	Styiarioides plumose		+		
	Dolichoglossus sp.		+		
	Arenicola marina		+		
	Autolytus sp.		+		
	Dasybranchus caducus		+		
	Phoronopsis viridis		+		
	Physcosoma sp.		+		
	Amphitrite sp.		+		
	Barnia clavata		+		
	Protula tubularia		+		+
Arthropoda	**Amphipoda**				
	Orchestia gammarella	+		+	+
	Concahecia spp.	+			
	Ampithoe remondi	+		+	+
	Gammarus locusta		+	+	+
	Corophium sp.	+	+	+	+
	Caprella acanthifera			+	+
	Anthura gracilis		+		
	Mysidacea				
	Mysis relicta		+		
	Anchialina agilis	+			
	Isopoda				
	Sphaeroma serratum			+	+
	Sphaeroma walkeri				+
	Dynamene bidentata			+	+
	Idotea baltica			+	+
	Cirripedia				
	Lepas sp.	+	+		
	Balanus perforatus	+		+	
	Balanus amphitrite		+		
	Ostracoda				
	Cypridina mediterraina	+			
	Insecta				
	Cricotopus mediterranous	+	+		+
	Nymphon gracile			+	
	Decapoda				

Group	Sampling year	1984	1986/87	2002/03	2004
	Species	**Fouda** *et al.* **(1985)**	**Aboul – Ezz (1988)**	**El-Shabrawy & Khalil (2003)**	**Fishar (2005b)**
	Lupa (Neptunus) pelagicus	+		+	
	Cancer sp.		+		
	Cancer pagarus				+
	Ocypode saratan	+			
	Geryon longipes				+
	Palaemon sp.		+		+
	Penaeus monoceros				+
	Penaeus japonicus			+	+
	Penaeus semisulcatus				+
	Penaeus kerathurus				+
	Metapenaeus stebbingi	+			+
	Stomatopoda				
	Squilla desmaresti	+			
	Squilla massawensis	+			
	Squilla mantis				+
Mollusca	**Bivalvia**				
	Brachiodontus variabilis	+	+	+	+
	Cerastoderma glaucum			+	+
	Cerastoderma sp.		+		
	Cerastoderma edule	+	+		
	Donax trunculus		+		+
	Tellina edentula		+		+
	Dosinia lupinus	+		+	+
	Gari depressa	+		+	
	Mactra corallina	+	+	+	+
	Arca lacteal		+		
	Mytilus galloprovinclalls		+		+
	Gastropoda				
	Patella sp.			+	+
	Barnea candida		+		
	Hydrobia ventrosa			+	
	Murex tribulus	+	+		+
	Rissoa ventrosa				+
	Gibbula ardens				+
	Cibbula sp.				+
	Thais haemastoma				+
	Pirenella conica	+		+	+
	Cerithium reticulatum		+		
	Cerithium vulgatum		+	+	+
	Cerithium scabridium	+			
	Cerithium kochi	+			
	Bulla sp.				+
Echinodermata	*Amphipholis squamata*			+	+
	Patiria miniata		+		
	Psammechinus sp.	+			
	Ophiothrix fragilis				+

8.2.2 Spatial and Temporal Distribution of Total Macrofauna

Distribution of macrobenthos in different sampling sites in Lake Bardawil showed remarkable changes from one site to another. The highest P. D. (763, 623 and 507 organisms/m^2) were recorded in stations 1, 2 & 3, respectively. This is mainly due to increase number of molluscs and arthropods. On the other hand, the lowest population density (113 and 137 organisms/m^2) were recorded in stations 10 and 4 (Fig. 8.8).

Sediment characteristics remarkably affected the distribution of benthos. Macrbenthos were limited in the inlets of lakes and there was evidence of greater spatial variability, which may be a consequence of disturbance caused by artificial inlets. The results indicated that stations nearby inlets (4 &10) have the lowest number of organisms compared with other stations. The highly populated sites were the eastern sites (stations 1, 2 & 3). These localities are

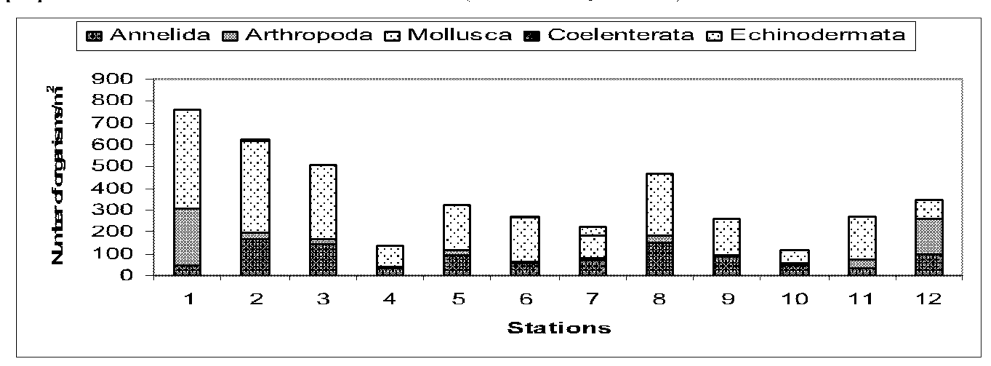


Fig.8.8. **Distribution of macrobenthic groups in Lake Bardawil (Fishar 2005b).**

characterized by dense vegetation, which gives a good refuge and grazing area and shelter for benthic organisms. Cluster analysis (Fig. 8.9) classified the sites into four main groups. The first group comprised sites 9, 6 & 10 (with high percentage of sand), the second group comprised sites 11, 12 & 1 (with high salinity), the third group comprised sites 2, 3 & 8 (with dense vegetation) and the fourth group comprised sites 5 & 7 (with high organic matter). Fish and fisheries can also affect the benthic community structure through predation and disturbance. Fish predation reduces macrofaunal abundance and limits the distribution of favorable macrofaunal organisms (Healey 1984). Stations 6, 7, 9 &10 showed a relatively low population density and diversity, mainly attributed to extensive fishing in these areas.

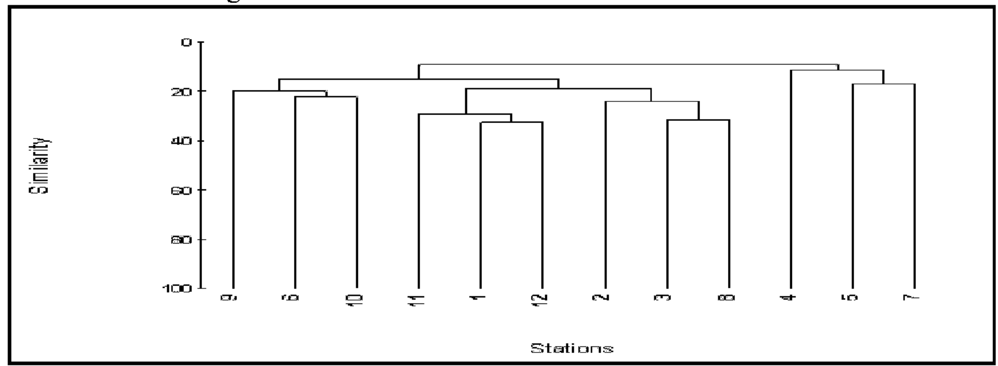


Fig. 8.9. **Cluster analysis similarity between sampling sites of macrobenthos in Lake Bardawil (after Fishar 2005b)**

Regarding temporal distribution of macrofauna, the highest P.D. was recorded during April with an annual average value of 630 organisms/m^2. A remarkable decrease was recorded during next months to reach 250 organisms/m^2 during June. The P.D. reincreased again to form the second peak (383 organisms/m^2) during September. The lowest average value (126 organisms/m^2) was recorded during November (Fig. 8.10).

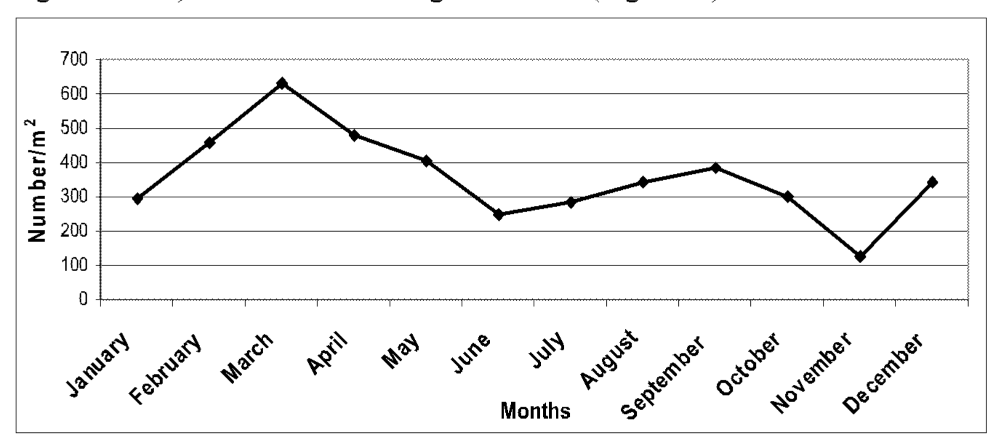


Fig. 8.10. **Monthly variations of total macrobenthos in Lake Bardawil (Fishar 2005b)**

8.2.3 Spatial and Temporal Distribution of the Recorded Groups

8.2.3.1 Coelenterata

As shown in Figs. 8.11 & 8.12, a coelenterate species (*Rhizostoma pulmo*) was recorded in the whole area. This species was recorded during January in two sites (stations 2 and 12) with the same average value (3 organisms/ m^2 for each).

8.2.3.2 Annelida

In sampling localities, stations 3, 4 & 8 were the most populated sites in the lake with annelids, where 170, 147 and 150 organisms/ m^2 were observed. The lowest average values of P.D. were recorded in stations 4 and 11 (Fig. 8.12). Concerning monthly variations of Annelida, P.D. showed their highest values during cold months (December and January). A remarkable decrease was observed in the next months of the year to reach the lowest value (17 organisms/m^2) during November (Fig. 8.11). The polychaete species *Capetella capitata, Nereis pelagica* and *Syllis variegata* are the most dominant annelid species in the lake.

8.2.3.3 Arthropoda

As shown in Table 8.2, Arthropoda was represented by six amphipods, three isopods, one stomatopod and one insect larva (*Cricotopus mediterranous*). The average density (P.D.) of Arthropoda in the whole investigated area was 50 organisms/m^2. The most eastern site (station1) and the most western site (station 12) were the most favorable grounds for arthropods where P.D. 260 and 160

organisms/m^2 were recorded, respectively. The minimum value of P.D. was reported in station 6 (Fig. 8.12).

As regards the temporal variation, two peaks appeared, the major one (140 organisms/m^2) during March and the minor one (73 organisms/m^2) during August. The arthropod species were missing during November (Fig. 8.11).

8.2.3.4 Mollusca

Mollusca was the most common group in the investigated area. It was represented by seven bivalves and eight gastropods (Table 8.2). It was common in all sections but with different densities. The highest number was recorded in eastern part of the lake (stations 1, 2 & 3) with average values of 457, 427 and 337 organisms/m^2, respectively. In the western part, station 8 was the most productive site with an average value of 287 organisms/m^2 (Fig. 8.12). On the other hand, the lowest value was recorded in station 10.

Concerning temporal distribution of macrofauna, the highest P.D. was recorded during March with an average value of 377 organisms/m^2. A remarkable decrease was recorded during next months to reach 140 organisms/m^2 during June. The P.D. reincreased again to the second peak (280 organisms/m^2) during September. The lowest average value (107 organisms/m^2) was recorded during November (Fig. 8.11). The species *Brachiodontus variabilis, Cerithium vulgatum, Pirenella conica, Mytilus galloprovinclalls* are the most dominant molluscan species in the lake.

8.2.3.5 Echinodermata

During the present study, two species of Echinodermata (*Ophiothrix fragilis* and *Amphipholis squamata*) were recorded in the whole area. Echinodermata was recorded in two sites (stations 6 and 7) with average values of 7 and 37 organisms/m^2, respectively (Fig, 8.12). Concerning the temporal distribution, the highest average value (13 organisms/m^2) was recorded during February. On the other hand, it was missing during January, March, April, May, June and October (Fig. 8.11).

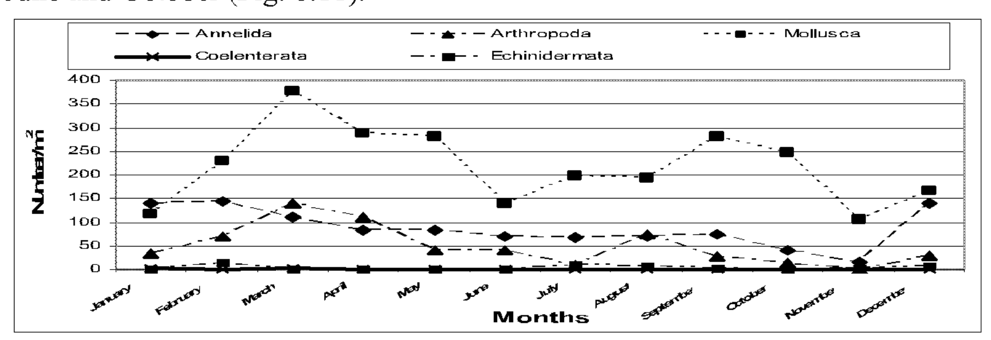


Fig. 8.11. **Monthly variations of different macrobenthic groups in Lake Bardawil (Fishar 2005b)**

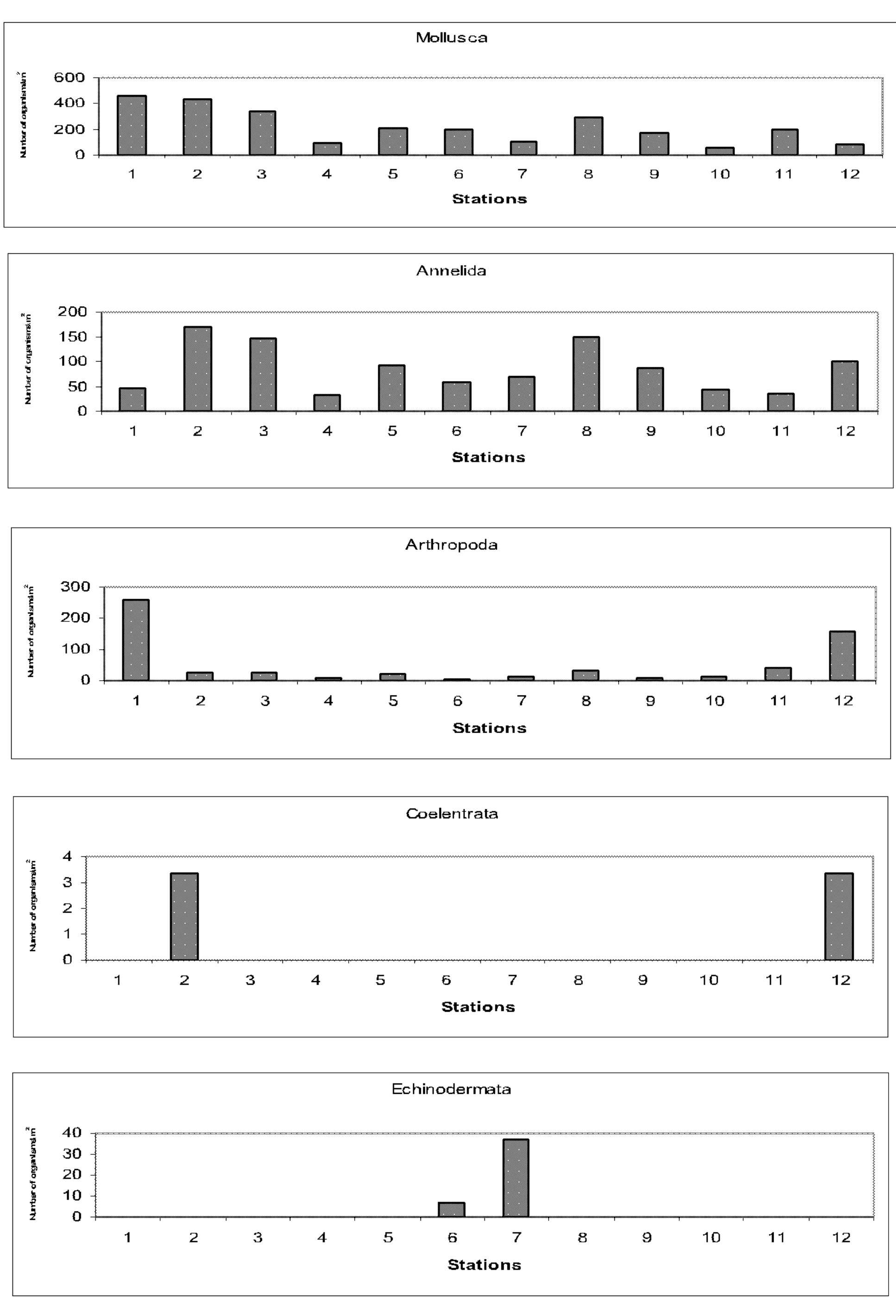


Fig.8.12. Distribution of different macrobenthic groups in the Lake Bardawil (Fishar 2005b)

8.2.4 Long Term Changes of Macrobenthos

Four sampling programs reflecting long-term changes of macrozoobenthos in Lake Bardawil were carried out during 1984 (Fouda *et al.* 1985), 1986 -1987 (Aboul-Ezz 1988), 2003 (El-Shabrawy & Khalil 2003) and 2004 (Fishar 2005b).

8.2.4.1 Density fluctuation

As shown in Fig. 8.13, the standing crop of total benthos during 1984 was 4164 organisms/m^2. P.D. showed a remarkable decrease (3711 organisms/m^2) during survey of 1986 – 1987 and continues their decrease in 2003 (2230 organisms/m^2) followed by a sharp drop during 2004 (359 organisms/m^2).

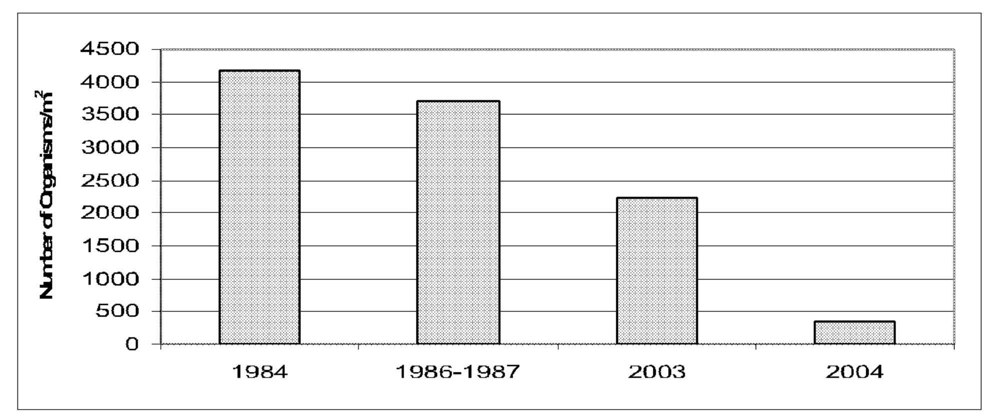


Fig.8 13. **Annual fluctuation of macrobenthos density during four periods (1984- 2004) (Fishar 2005b)**

8.2.4.2 Variations in species composition

The community composition of macrobenthos in Lake Bardawil showed remarkable changes from one survey to another. In 1984, Arthropoda was the most common group followed by Mollusca and Annelida. In 1986/1987, Annelida was the most predominant group in the lake, forming 41% of the total P.D. of benthos followed by Arthropoda (32.7 %), then Mollusca (12.6 %). In 2003, the same trend was observed but with different percentages (Fig. 8.14). In 2004, Mollusca occupied the first position, with 60.79 % of P.D. followed by Annnelida (24.05 %) and Arthropoda (14 %).

8.2.4.3 Variations in biodiversity

As shown in Fig. (8.15), 33 macrobenthic species were recorded during 1984, including 4 annelid species, 9 molluscs, 14 arthropods, one nematode and 2 echinoderms. This number increased to 47 macrobenthic species during 1986 - 1987. Annelids were the most predominant in the lake with 23 species. Mollusca occupied the second position of benthos and was represented by 12 species, followed by Arthropoda represented by 9 species. Echinodermata, Coelenterata and Nematoda were represented by only one species for each,

namely: *Patiria miniata*, *Rhizostoma pulmo* and *Enoplus meridionalis*, respectively

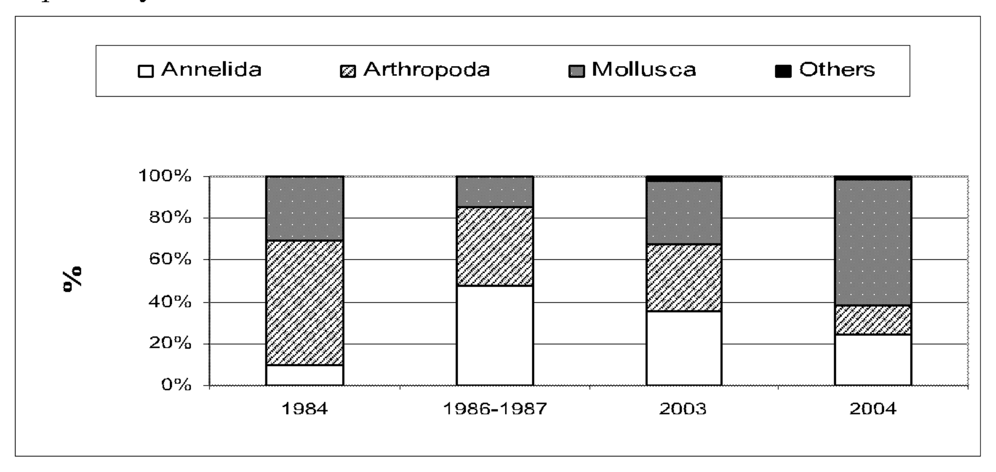


Fig. 8. 14. **Annual fluctuation of percentage composition of macrobenthic groups for different surveyed years (Fishar 2005b).**

In 2003, the species composition changed dramatically. Disappearance of nine annelids and 3 molluscs species was accompanied by the appearance of three arthropods, beside one nemartine species, one echinoderm and one coelenterate species.

In 2004, the macrobenthic fauna increased to 52 species. The numbers of species recorded were 19 Arthropoda, 16 Mollusca, 14 Annelida, two species of Echinodermata and one species of Coelenterata.

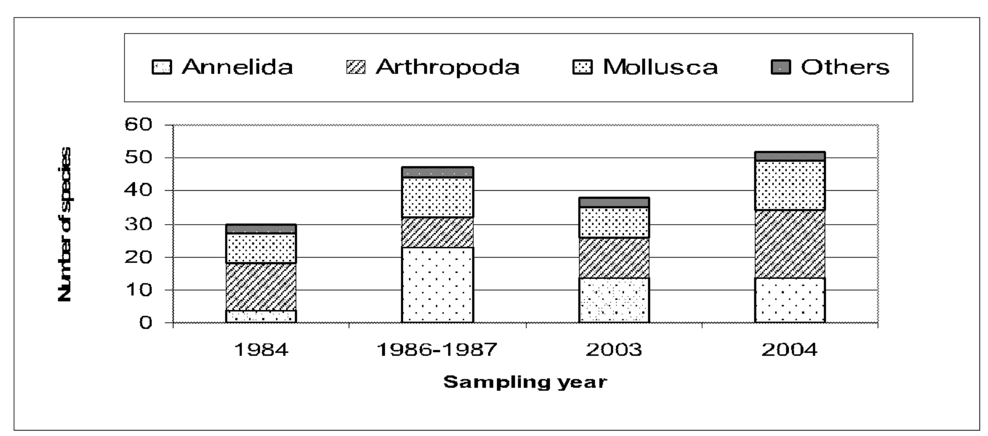


Fig. 8. 15. **Annual fluctuation of macrobenthos diversity (number of species recorded) during different surveyed years (Fishar 2005b)**

The previous results showed that macrobenthic community composition changed by time. During 2003, only two molluscan species of 1986-1987 survey were recorded. At the same time, 24 % of species recorded were

previously recorded during 1986-1987 and 43 % of such species were previously recorded during 2003 (Fishar 2005b). The population density of total macrobenthos has dramatically declined from year to another, especially in 2003 and 2004. Since 1995, fisheries catch composition has been changed. Contribution of the most economic species such as the sea bream and sea bass, has sharply declined from 56.5 %, in the 1982-1988, to about 8.6 % in 2003, of the total catch. Change in fish community certainly affects macrobnethos assemblages, since the declined fish species are mainly bottom feeders. As an instant, Mollusca comprised the highest volume of *Sparus aurata* diet. It formed up to 33.24% and was found in 89.63%, while Crustacea constituted about 8.11 % by volume (Khalifa 1995). Accordingly, the decrease in the predators leads to reduction of the grazing pressure upon the prey, and in turn increase and flourishing of the prey. That could logically explain the increasing in the diversity and abundance of Mollusca during the present study than the previous ones.

This change in fish community, which consequently changes the whole ecosystem of the lake, encourages us to recommend establishing a monitoring program to follow up changes in the lake ecosystem, especially the benthic fauna that will be of great help in the management of such important water body.

8.3 SUMMARY

Meiobenthic community in Lake Bardawil during 2002/03 consisted of 20 species belonging to four groups namely: Foraminifera (4 species), Ostracoda (2 species), Nematoda (3 species) and Copepoda (3 species). Nature of the sediment and organic matter were the main factors affecting the meiofaunal abundance and distribution. Anthropogenic activities (intensive fish trawling and artificial inlets) seem to affect the distribution of total meiobenthos.

Macrobenthic community during 2004 comprised 52 species belonging to five phyla; Coelenterata, Annelida, Arthropoda, Mollusca and Echinodermata. The abundance of macrobenthic species was closely correlated with nature of bottom sediments, organic matter and salinity. The long-term changes in macrozoobenthos density of Lake Bardawil (1984- 2004) showed a remarkable decrease from one year to another, that is attributed to changes in fish community structure. However, a remarkable increase in population density of Mollusca was recorded during 2004, because of declining of *Sparus aurata* production, which is mainly a bottom feeder that depends mainly on Mollusca in their diet.

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8.5 PLATES OF MACROBENTHOS

(After: Photo gallery of Marine Biodiversity and Ecosystem Functioning EU Network of Excellence (MarBEF)

http://www.marbef.org/modules.php?name=Photogallery&album=15, and other sources

Plate 8. 1

Orchestia gammarella
Ampithoe remondi
Gammarus locustas
Corophium sp.
Idotea baltica
Caprella acanthifera

Plate 8.2

Sphaeroma sp.
Cricotopus mediterranous
Geryon longipes
Cancer sp.
Balanus amphitrite
Balanus perforatus

Plate 8.3

Penaeus semisulcatu
Penaeus japonicus
Penaeus monoceros
Metapenaeus stebbingi
Lepas sp.
Squilla sp.

Plate 8.4

Neries pelagica
Lumbriconeries funchalenais
Cirratulus cirratus
Dolichoglossus sp.
Hydroides elegans
Syllis variegate

Plate 8.5

Tubificid sp.
Myxicola infundibulum
Filograna implexa
Polydora sp.
Sabella fabricia
Capetella capitata

Plate 8.6

Eunica torquata
Eupolymania nebulosa
Neries diversicolor
Arnicola marina

Plate 8.7

Brachiodontus variabilis
Cerastoderma glaucum
Arca lacteal
Dosinia lupinus
Donax trunculus
Mytilus galloprovinclalls

Plate 8.8

Gari depressa
Mactra coralline
Pirenella conica
Patella sp.

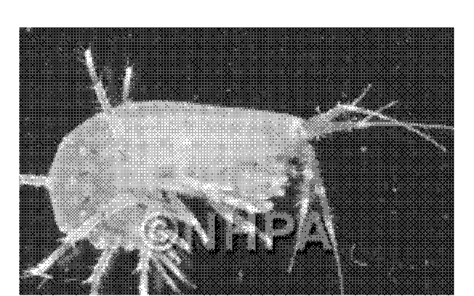
Plate 8.9

Hydrobia ventrosa
Cerithium vulgatum
Thias haemastoma
Bulla sp.

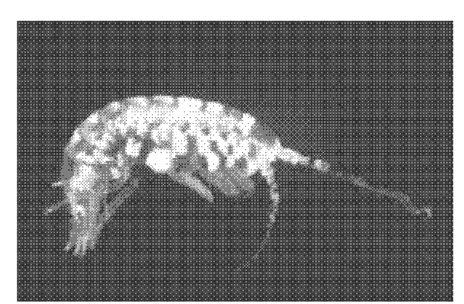
Plate 8.10

Amphipholis squamata
Ophiothrix fragilis
Rhizostoma pulmo
Actinia equine

Plate 8.1



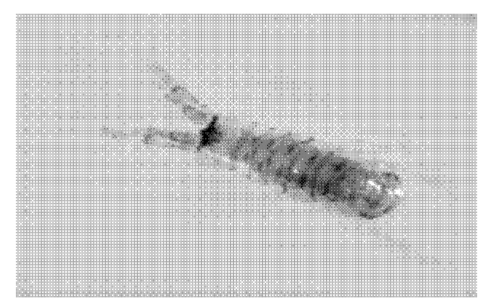
Orchestia gammarella



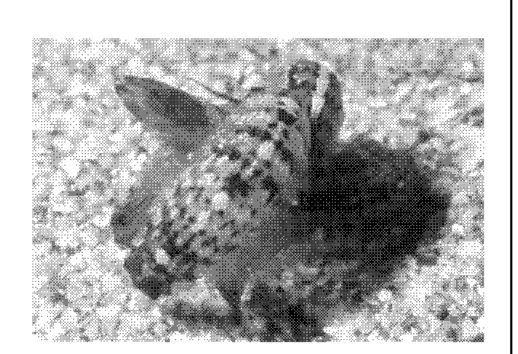
Ampithoe remondi



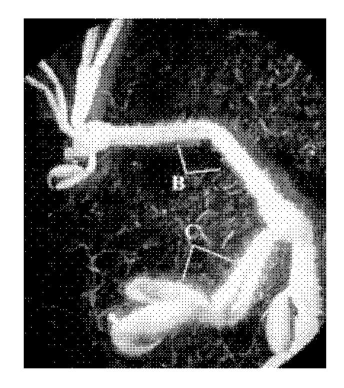
Gammarus locusta



Corophium sp.

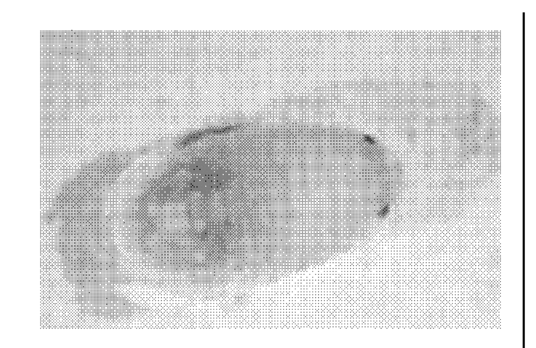


Idotea baltica

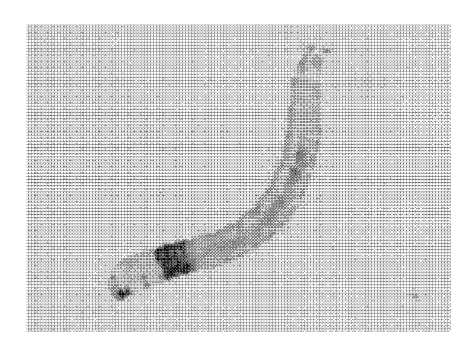


Caprella acanthifera

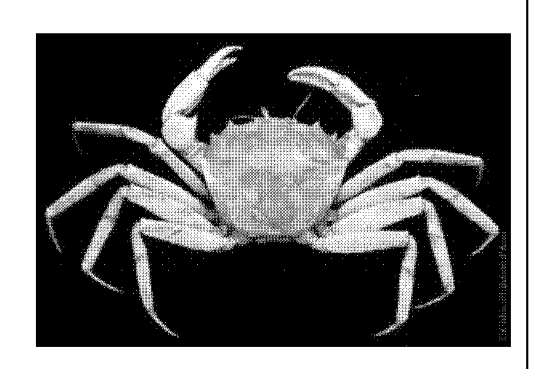
Plate 8.2



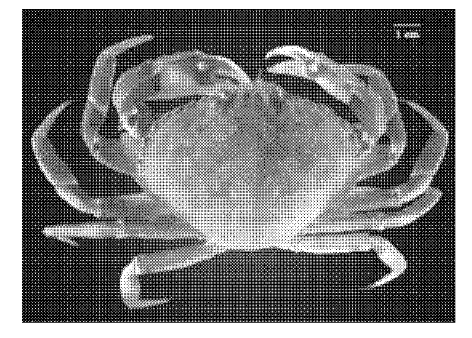
Sphaeroma sp.



Cricotopus mediterranous



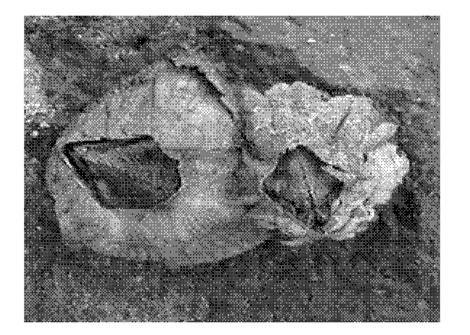
Geryon longipes



Cancer sp.

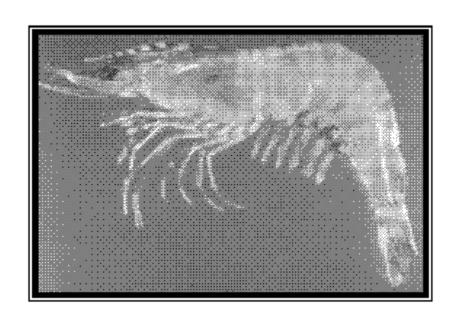


Balanus perforatus

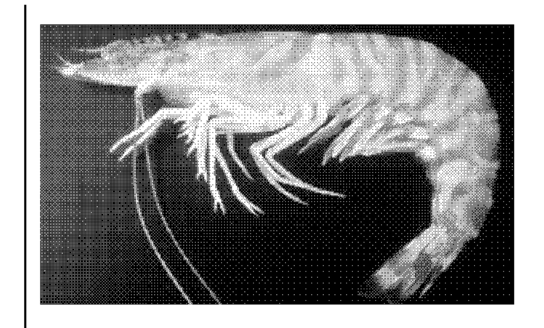


Balanus amphitrite

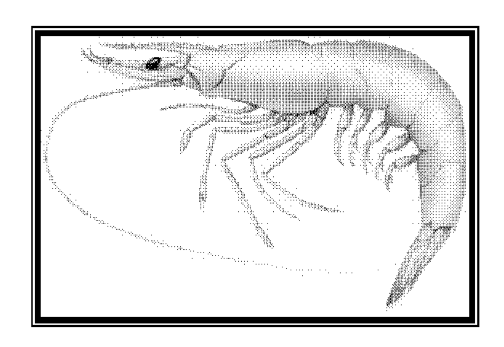
Plate 8.3



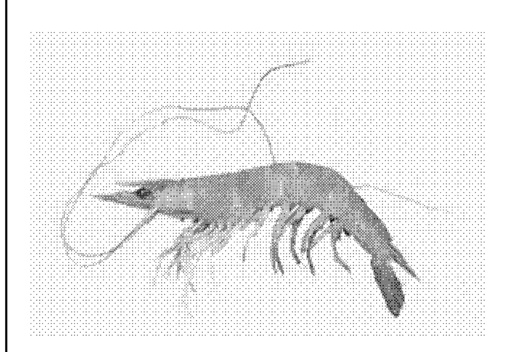
Penaeus semisulcatus



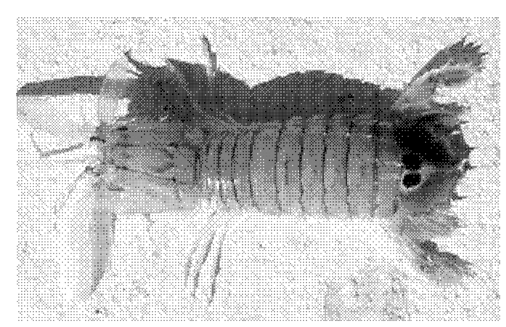
Peneaus japonicus



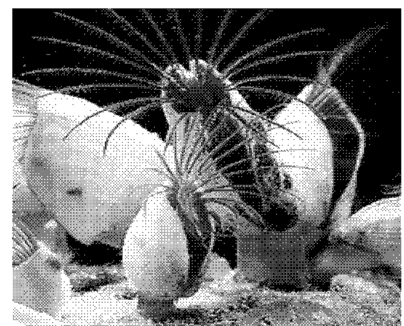
Metapenaeus stebbingi



Penaeus monoceros

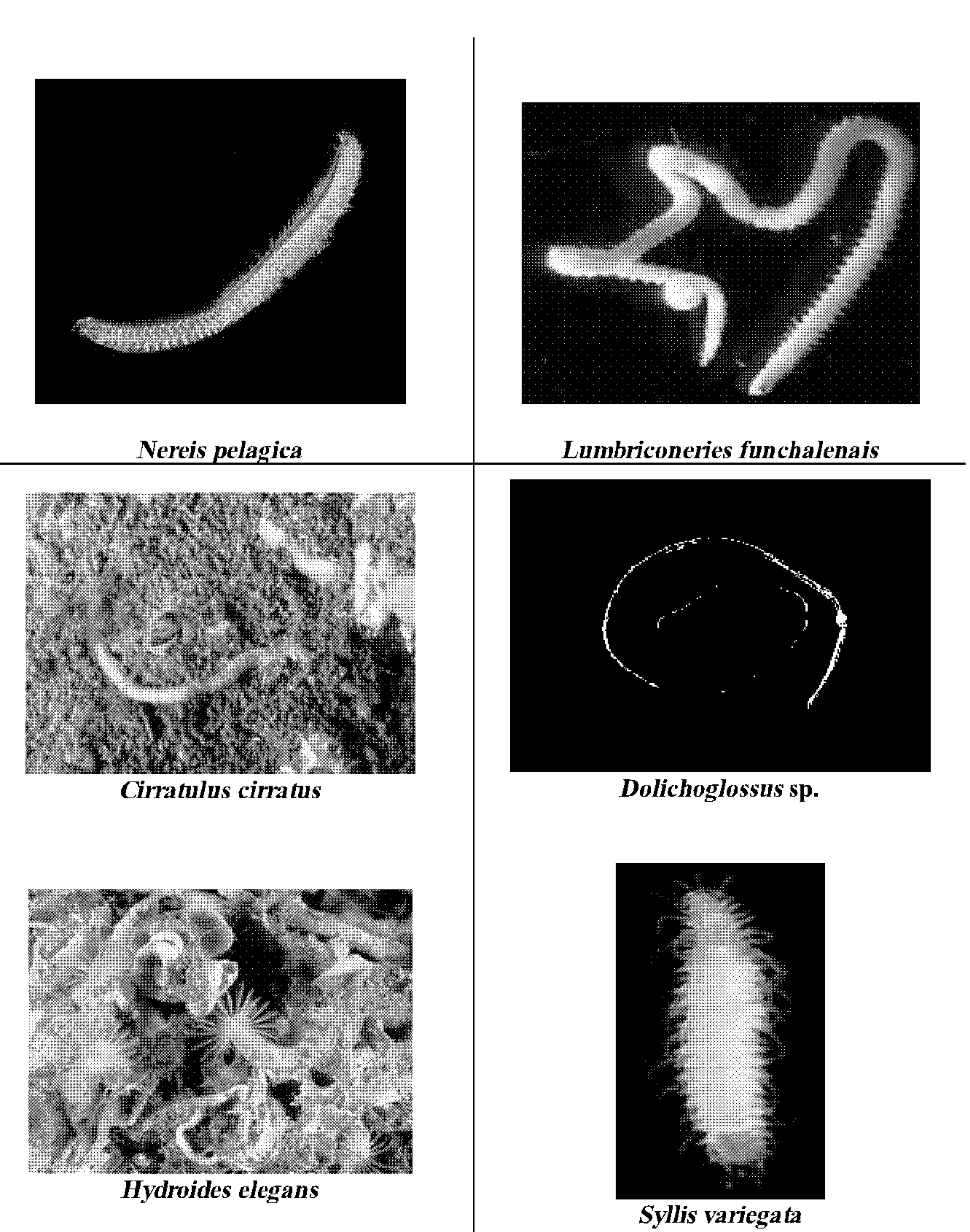


***Squilla* sp.**



***Lepas* sp.**

Plate 8.4



Nereis pelagica

Lumbriconeries funchalenais

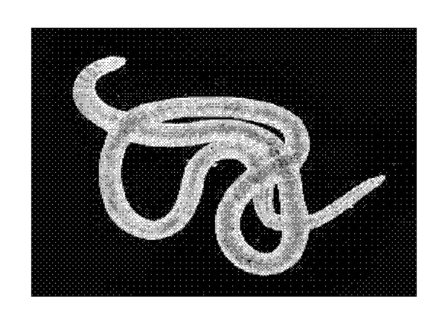
Cirratulus cirratus

Dolichoglossus **sp.**

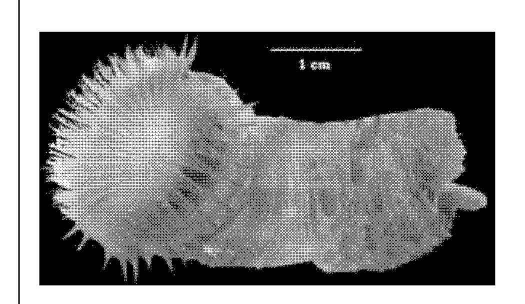
Hydroides elegans

Syllis variegata

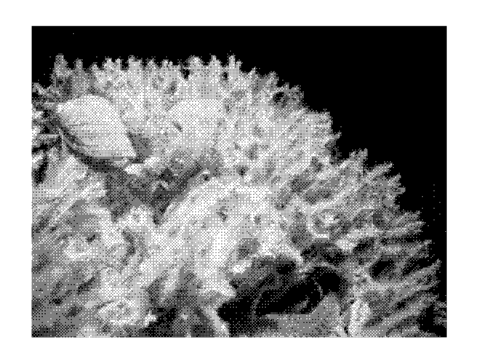
Plate 8.5



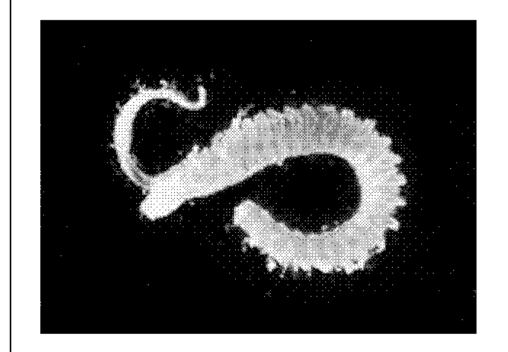
Tubificid sp.



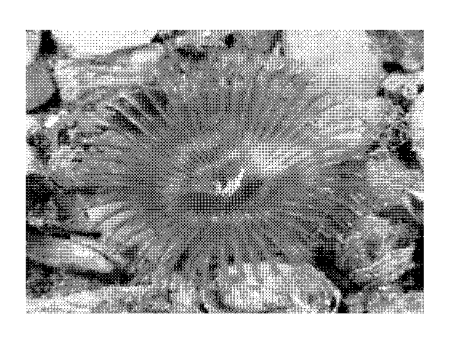
Myxicola infundibulum



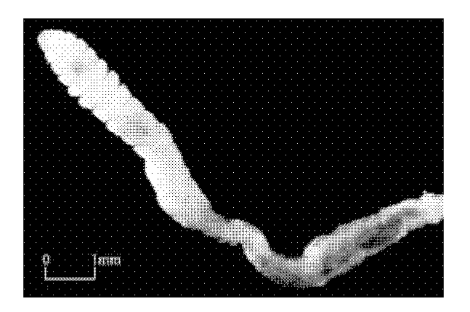
Filograna implexa



Polydora sp.

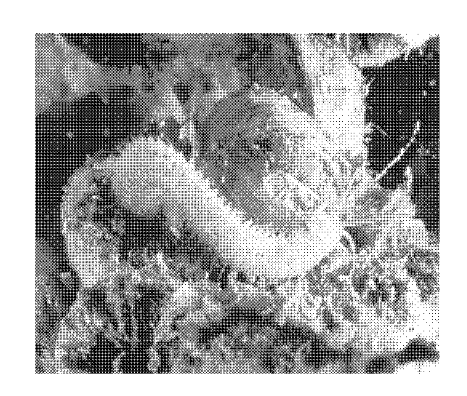


Sabella fabricia

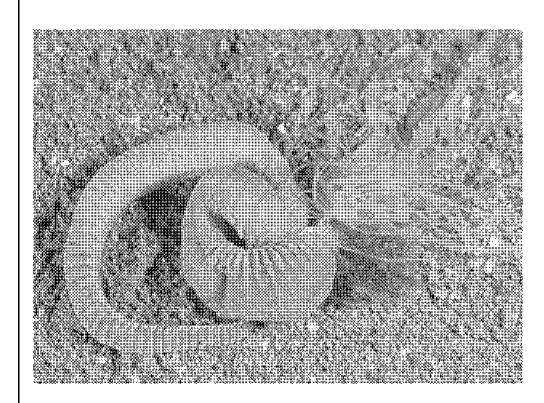


Capetella capitata

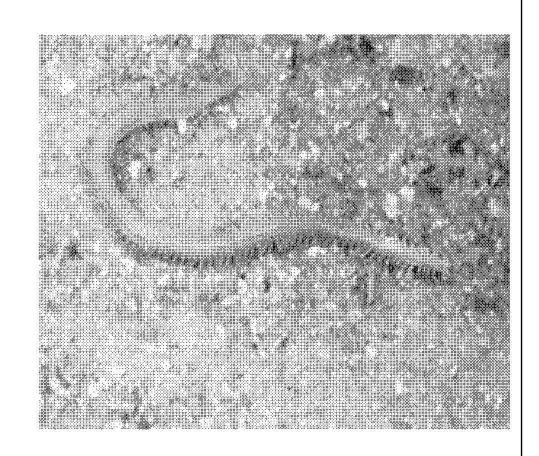
Plate 8.6



Eunica torquata



Eupolymania nebulosa

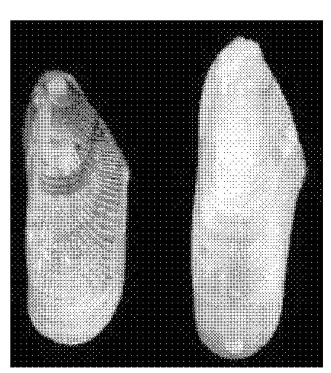


Neries diversicolor

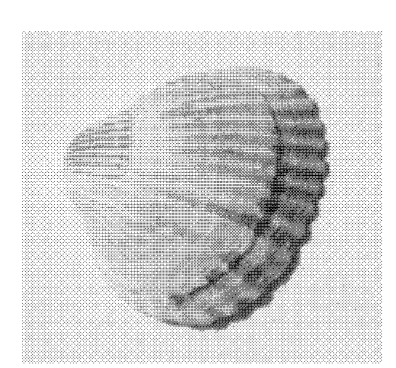


Arnicola marina

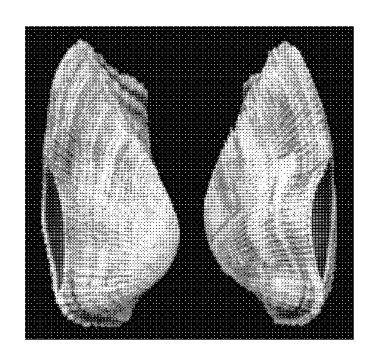
Plate 8.7



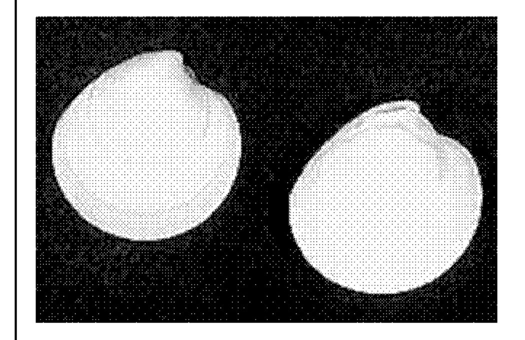
Brachiodontus variabilis



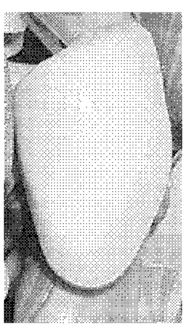
Cerastoderma glaucum



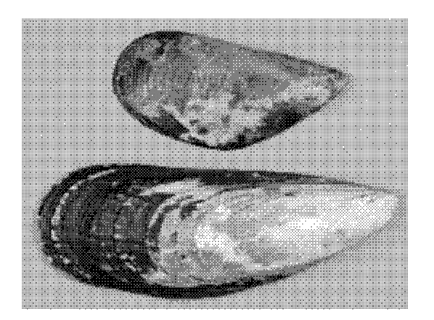
Arca lacteal



Dosinia lupinus

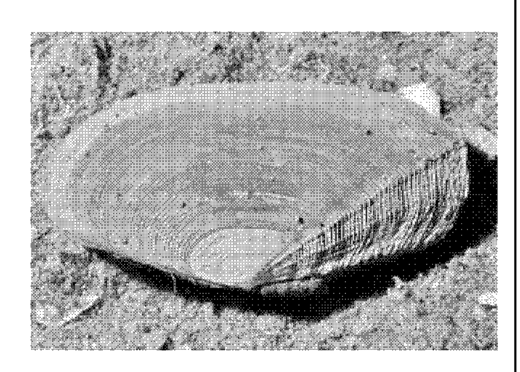


Donax trunculus

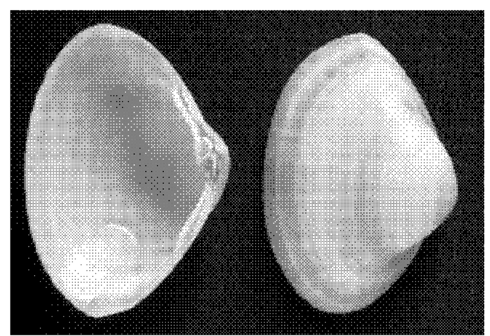


Mytilus galloprovinclalls

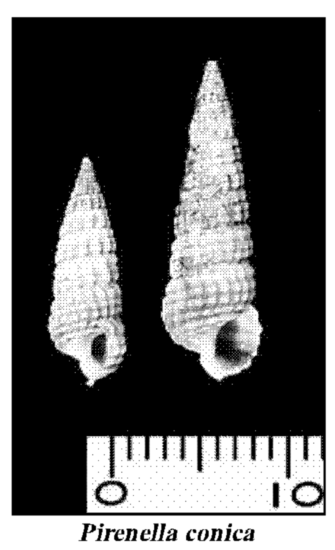
Plate 8.8



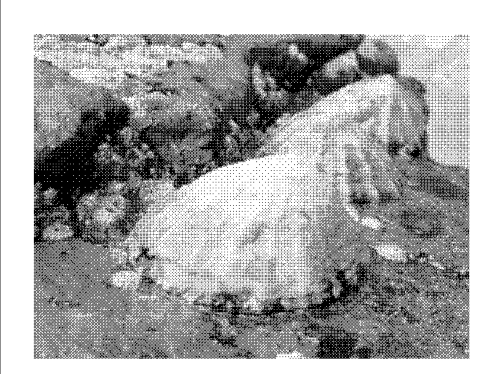
Gari depressa



Mactra coralline

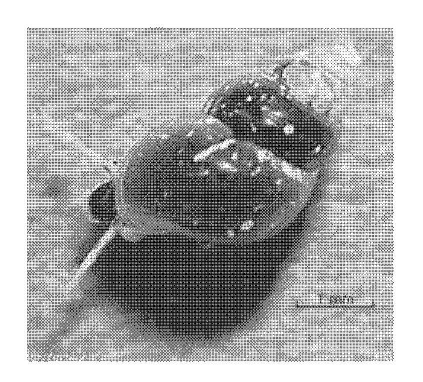


Pirenella conica

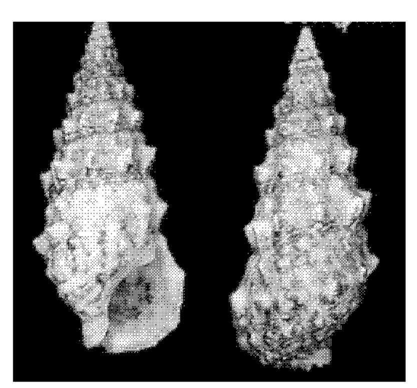


Patella sp.

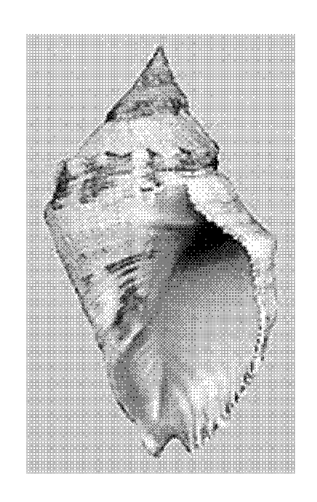
Plate 8.9



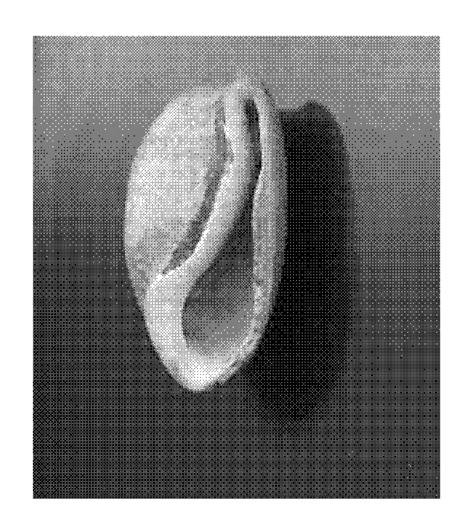
Hydrobia ventrosa



Cerithium vulgatum

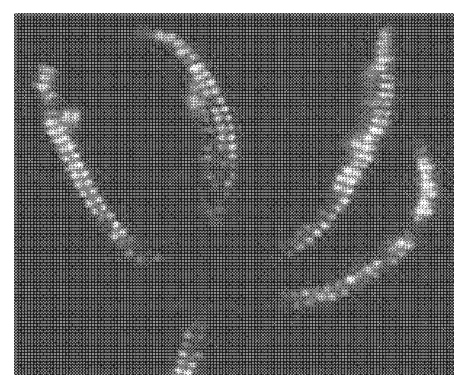


Thias haemastoma

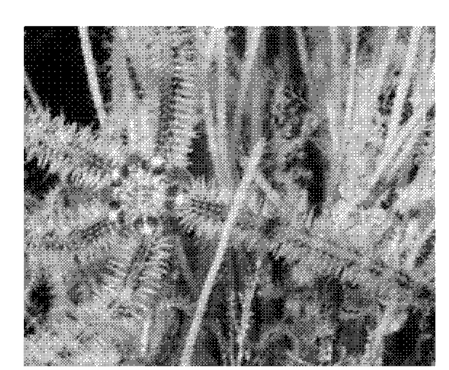


***Bulla* sp.**

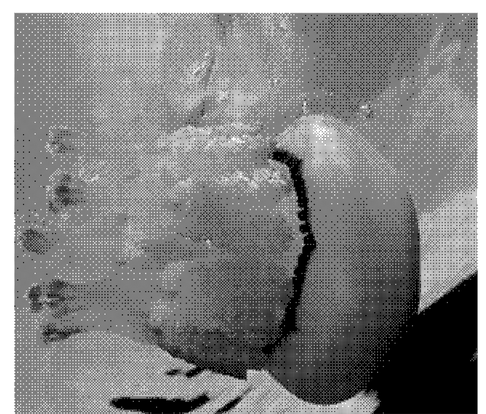
Plate 8.10



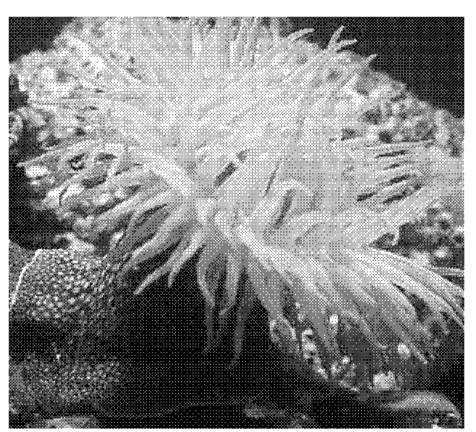
Amphipholis squamata



Ophiothrix fragilis



Rhizostoma pulmo



Actinia equine

Chapter 9
Fishes and Fisheries

It has long been known that lagoons are often very productive and yield good catches (Vannucci 1969, Ben-Tuvia 1979). This is also true for the Bardawil Lagoon.

Historically, Bardawil Lagoon (also called Sabkhat El Bardawil or the Sirbonian Lagoon) is named after King Baldwin I, who took part in the Crusades and according to tradition was killed at El-Arish (Ben-Tuvia 1979). During the Roman period, the lagoon was called Port Sirbon. Many historians and archeologists speculate that the Exodus of the tribes of Israel from Egypt passed through this area and the biblical «Red Sea» or «Sea of Reeds» is the Bardawil Lagoon. Some recent excavations on the wide part of the sandy bar (Kals or Mount Cassius) have been reported by Dothan (1969) who found evidence of settlements from the period of the Early Iron Age and a town, evidently Cassius, from the Hellenistic-Roman Period.

The Bardawil Lagoon is situated along the northern coast of Sinai, from a point about 45 km east of Port Said and extending to a point 20 km west of El-Arish (Fig. 1). Its geographical boundaries extend from 32° 40" to 33 ° 30" east longitude and from 31 ° 03" to 31° 14" north latitude. Without man's interference, the area of the Bardawil Lagoon would be a salty swamp, flooded during the winter storms. Jarvis (1941) described it as a «huge, dry, clay pan», rented to a contractor who cut a channel from the lagoon to the sea and used it for grey-mullet fishery.

The lagoon covers an estimated area of about 650 km^2, with a maximum length along the east-west axis, of 90 km and a maximum width, along the north-south axis, of 22 km. It is extremely shallow; its depth ranges from 0.5 m to a rather rare 3 m. A long narrow sandbar of about 100 km long, with a maximum width of 2 km, separates the lagoon from the Mediterranean Sea. Three inlets connect the lagoon with the sea; two artificial in the west

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(Boughaze I & Boughaze II) and an eastern natural one at Zaranik. The latter has a little effect on the flooding of the lagoon or the salinity of its water because Zaranik is extremely shallow and separated from the rest of the lagoon by a series of islets and sand bars, whereas the two artificial openings are essential in order to ensure satisfactory exchange of water between the lagoon and the open sea.

Lake Bardawil is so far considered the cleanest marine water body in Egypt, as well as in the entire Mediterranean region and the vast hypersaline mud flat (known as sabkhat El-Bardawil), occupying the eastern fringes of the Lake, is the largest in the country.The lake is an important wintering and staging area for large numbers of water-birds, consequently it has been designated as an Important Bird Area (IBA) by BirdLife International . Furthermore, it is an important source of local fishery in north Sinai and the country.

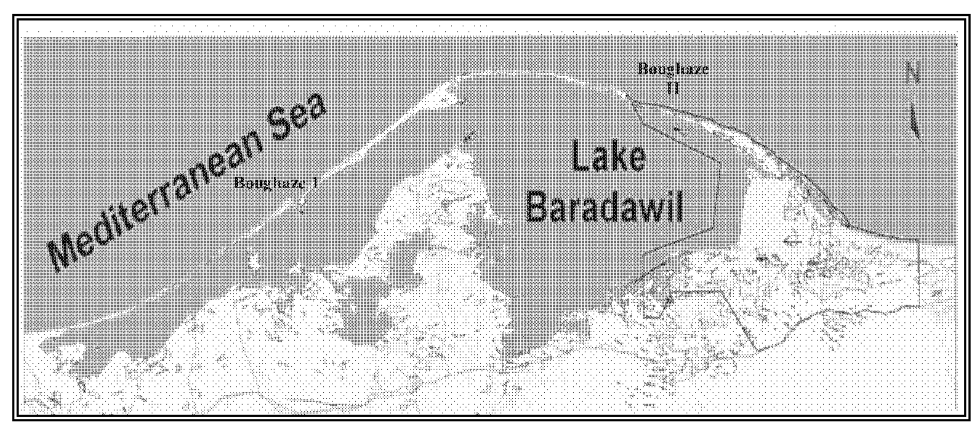


Fig. 9.1. **Map of the northern side of Sinai showing the location of Bardawil Lagoon**

9.1 FISH SPECIES DIVERSITY

The organisms inhabiting the Lagoon originate from the Mediterranean Sea and Red Sea via Suez Canal. However, the pronounced fluctuations in the hydrographic and biological conditions prevailing in the Lagoon (strong seasonal and diurnal changes in salinity and temperature) limit the number of species that are capable of thriving there to a few dozens only (Ben-Tuvia 1979). The species found are by nature eurytopic, especially in their tolerance to both low and high salinities. Their ability to withstand extreme changes of environmental conditions implies *a priori* that they may be suitable for fish culture. In fact, all the common commercial fishes of the Bardawil Lagoon, namely gilthead bream (*Sparus aurata*), grey mullets (Mugilidae), sea bass (*Dicentrarchus labrax*) and the common sole (*Solea solea*) are known to be commercially or experimentally cultivated in various parts of the world. Ben-Tuvia (1979) divided the common fish of the Bardawil Lagoon into two categories:

1. The larger, commercially exploited species which migrate for spawning to the open sea.
2. Small fish which evidently spawn in the Lagoon itself.

The number of Red Sea immigrants, in proportion to the total number of species, is higher in Bardawil than in the eastern Mediterranean Sea. From the total of 36 Red Sea species, 17 have been collected in Bardawil Lagoon, including two species; *Crenidens crenidens* and *Authistes puta* that have not as yet been found along the other sections of the Mediterranean coast. The Red Sea species in Bardawil constitute about 25% of the total number of species collected (Ben-Tuvia 1984). Ben-Tuvia (1975) listed about 60 species of fishes collected from the lagoon during 1970s, but recently, Khalil *et al.* (2002) listed up to 44 species found in Bardawil Lagoon. Table 9.1 shows the fish and crustacean species of Bardawil as recorded in the literature and observed during the field trips to the lagoon landing sites during the last ten years.

9.2 HISTORY OF EXPLOITATION AND CATCH COMPOSITION

The Egyptian Government began leasing the lagoon and recording the catches on regular basis in 1924 (Ameran 2004). According to different reports, the catch was 196 tons in season 1925 and increased gradually to reach 371 tons in 1931 and decreased again to 317 tons in 1932 (Fouad 1926, Abou Samra 1935, Faouzi 1938). *Mugil cephalus* and *Liza ramada* were the most important species in catches (Fig. 9.2).

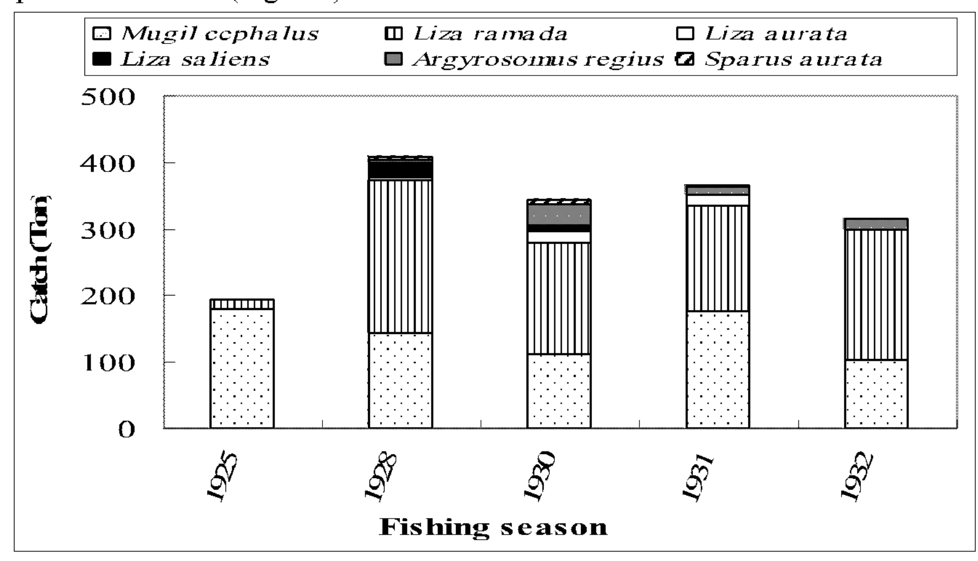


Fig. 9.2. **Fish production by species of Bardawil Lagoon during the period from 1925 to 1932 (Fouad 1926, Abou Samra 1935).**

Table 9.1. **Fish species in Bardawil Lagoon**

Family	Scientific name	English name	Arabic name
Anguillidae	*Anguilla anguilla* (Linnaeus 1758)	Eel	سمك ثعبان
Atherinidae	*Atherina boyeri* (Risso 1810)	Sand smelt	بساريا
Belonidae	*Tylosurus acus* (Lacepède 1803)	Garfish	خرم
Cichlidae	*Tilapia zillii* (Gervais 1848)	Tilapia	بلطى اخضر
Hemiramphidae	*Hemiramphus far* (Forsskål 1775)	Halfbeak	ابومنقار
Moronidae	*Dicentrarchus labrax* (Linnaeus 1758)	European sea bass	قاروص
	Dicentrarchus punctatus (Bloch 1792)	Spotted sea bass	نقط
Mugilidae	*Mugil cephalus* (Linnaeus 1758)	Flathead grey mullet	بورى
	Liza ramada (Risso 1826)	Thinlip grey mullet	طوبارة
	Liza aurata (Risso 1810)	Golden grey mullet	دهبانة
	Liza saliens (Risso 1810)	Leaping mullet	جرانه
	Liza carinata (Valenciennes 1836)	Roving grey mullet	سهلية
	Chelon labrosus (Risso 1826)	Thicklip grey mullet	كالونه
Mullidae	*Mullus barbatus* (Linnaeus 1758)	Red mullet	بربوني
	Mullus surmuletus (Linnaeus 1758)	Striped red mullet	بربوني
Pomadasyidae	*Pomadasys stridens* (Forsskål 1775)	Grunts	باميا
Sciaenidae	*Argyrosomus regius* (Asso 1801)	Meagre	لوت
	Umbrina cirrosa (Linnaeus, 1758)	Corb	شفش
Scorpaenidae	*Scorpaena porcus* (Linnaeus, 1758)	Scorpionfish	عقرب
Serranidae	*Epinephelus aeneus* (Geoff. St. Hilaire 1817)	White grouper	وقار
Carangidae	*Caranx rhonchus* (Geoff. St. Hilaire, 1817)	False scad	شنيور
Siganidae	*Siganus rivulatus* (Forsskål 1775)	Rabbit fish	سيجان
	Siganus luridus (Rüppell 1828)	Rabbit fish	سيجان
Soleidae	*Solea aegyptiaca* (Chabanaud 1927)	Egyptian sole	موسي
	Solea solea (Linnaeus 1758)	Common sole	موسى
Sparidae	*Sparus aurata* (Linnaeus 1758)	Gilthead sea bream	دنيس
	Lithognathus mormyrus (Linnaeus 1758)	Striped sea bream	غزيلة
	Dentex dentex (Linnaeus 1758)	Common Bogue	عضاض
	Boops boops (Linnaeus 1758)	Bogue	موزة
	Crenidens crenidens (Forsskål 1775)	Karenteen sea bream	موزة
	Diplodus annularis (Linnaeus 1758)	Annular seabream	شرغوش
Teraponidae	*Terapon puta* (Curier 1829)	Small-scaled terapon	باميا
	Pelates quadrilineatus (Bloch 1790)	Four-lined terapon	جربوع
Syngnathidae	*Hippocampus fuscus* (Rüppell 1838)	Sea horse	حصان البحر
	Syngnathus spp.	Sea horse	حصان البحر
Penaeidae	*Penaeus japonicus* (Bate 1888)	Kuruma shrimp	جمبرى يابانى
	Penaeus kerathurus (Forsskål 1775)	Triple-grooved shrimp	جمبرى قزازى
	Metapenaeus stebbingi (Nobili 1904)	Peregrine shrimp	جمبرى أبيض
	Penaeus semisulcatus (De Haan 1844)	Green tiger prawn	جمبرى سويسي
	Trachypenaeus curvirostris (Stimpson, 1860)	Southern rough shrimp	جمبرى أبوليفة
	Metapenaeus monoceros (Fabricius 1798)	Speckled shrimp	جمبرى أحمر
Squillidae	*Erugosquilla massavensis* (Kossmann 1880)	Mantis shrimp	شيكال
Portunidae	*Portunus pelagicus* (Linnaeus 1758)	Blue swimmer crab	كابوريا
	Callinectes sapidus (Rathbun, 1896)	Swimmer crab	كابوريا حجارى

Fouad (1926) stated that the concession was first given for the period from 1905 to 1911 at 1000 LE per year. Later, in 1911, the concession was renewed for eight years at yearly 1200 LE. However, in 1914, during World War I, martial authorities prohibited fishing activities in the lagoon. In 1924, the concession of the lagoon has been leased for five years at 810 LE yearly. By 1950, the concessionaire, Mr. Abu-Zikri, decided to intensify his operation. He firstly invested in opening two inlets from the sea; one on the east side and the second on the west side, to stabilize the lagoon as a fishing ground. Then, he introduced fish fry of *Sparus aurata* from Italy to the lagoon in 1952 (Ameran 2004).

El-Zarka & Koura (1965) remarked that the catch of the Gilthead sea bream from the two depressions; Bardawil and Port-Fouad, was five times as much as that taken from the Mediterranean Sea. Then, the whole production average reached approximately 2310 tons per year (2918, 2285, 1726 tons during years 1962, 63 and 64 respectively). The catch was composed mainly of the Gilthead sea bream, with an average yield of about 48.49% of the total catch (Sadek & Ameran 1988).

After 1967 war, the concessionaire had to cease his activities in the lagoon due to the Israeli occupation. Under the Israeli administration, people from El-Arish and Bir El-Abd, including some Bedouins, were encouraged to fish in the lagoon. The annual catches of the Lagoon during the period 1968-1978 varied from 900 in 1971 to 2650 tons in 1977, and also showed considerable variations in the species composition (Fig. 9.3). These variations reflect the influence of three main factors: 1. changes in the salinities prevailing in the Lagoon; 2. increase in fishing effort; 3. new fishing regulations introduced in years 1973-1975 (Ben-Tuvia 1979).

Because of the progressive silting of the two inlets; Boughazes 1 & 2 in the years 1969-1971, the salinities increased considerably. In normal years, the salinities in the main fishing area of the central portion of the Lagoon vary between 42-55 ‰ but in 1970, the salinities recorded in the same area were between 50-73 ‰ (Ben-Tuvia 1979). At the southern end of the Lagoon, the salinity reached 110 ‰ in November 1970. In 1971, dredging of the openings took place and the salinities decreased accordingly. During the following years, the dredging was carried out every second year, which proved to be sufficient to maintain the biological equilibrium in the Lagoon.

There is no doubt that the well-being of the commercial fish populations depends to a great extent on the level of the salinities. In periods of high salinities, the commercial fishes concentrated close to the openings and disappeared from many areas of the Lagoon, where the salinities exceeded 60 ‰. Fish caught in areas of high salinities often showed diseased eyes. Many grey mullets were thin and their flesh macerated (Ben-Tuvia 1979).

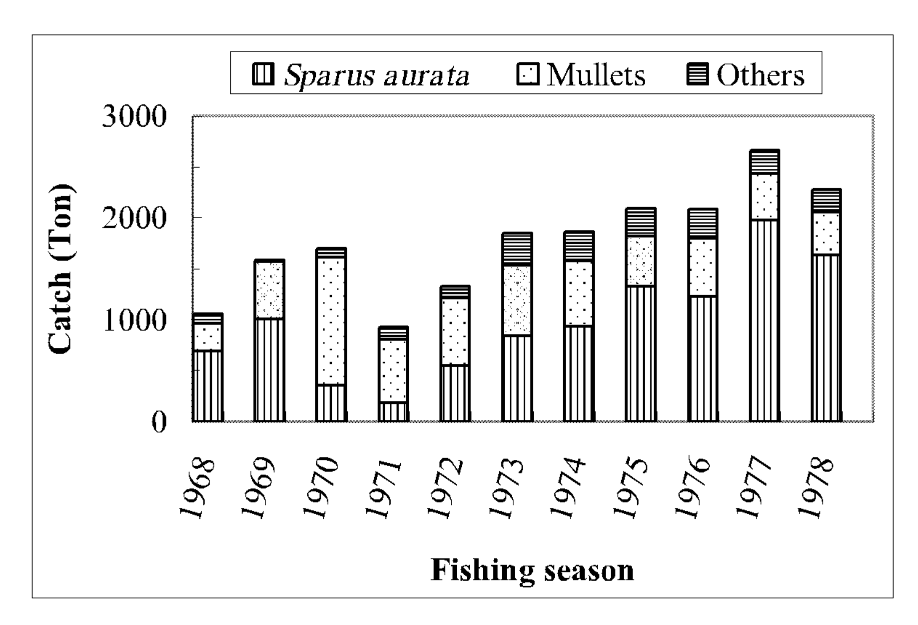


Fig. 9.3. **Fish production by species of Bardawil Lagoon during the period from 1968 to 1978 (Ben-Tuvia 1979).**

A striking decrease in the catch of the gilthead bream (*Sparus aurata*) can be seen in the years 1969-1971, from about 1,000 tons in 1969 to only 180 tons in 1971; one year after the 1970 peak of high salinities. In the years 1968-1969 and 1973-1977, the gilthead bream constituted between 48-74 % of the total catch. It is assumed that the abnormally high salinities prevent both the adult and the young fish from settling in the Lagoon (Ben-Tuvia 1979).

The high salinities also affected the catch composition of other groups of commercial fishes. Thus, in 1970-1972, *Liza ramada* appeared in much greater quantities than in other years, on account of the reduced catches of *Mugil cephalus*, while *Dicentrarchus punctatus* was much more abundant than usual.

Generally, *Sparus aurata* was commercially the most important fish during this period. Mugilids constituted 30- 60 % of the catch; among them *Mugil cephalus* constituted the bulk of the catch; while *Liza ramada, Liza aurata, Chelon labrosus, Liza saliens* and *Liza carinata* were caught in some numbers (Ben-Tuvia 1979). Both *Dicentrarchus labrax* and *Dicentrarchus punctatus* were common but the former one was more numerous and attained larger size. *Solea solea* and *Argyrosomus regins* were caught in small quantities. A Red Sea immigrant *Crenidens crenidcns* could occasionally be found in the commercial catch.

Among the small fish, *Atherina boyeri* was the most abundant. Both *Aphanius dispar* of the Red Sea origin and the peri-mediterranean *Aphanius*

fasciatus were common. The bottom was inhabited by two species of gobiids and a burrowing eel-like *Apterichthys caecus*. *Syngnathus abaster* and *Hippocampus* sp. have been occasionally collected among plants.

During this period, three kinds of fishing gears were used in the Bardawil Lagoon. 1. A purse-seine called locally Cionchiola which is an adaptation of the net used in the Mediterranean Sea for sardines and anchovies. Its use started in 1970. 2. Trammel-net under the local name of Dabba or Ambattan. 3. Beach-seine or Jaraff. The fishing effort increased continuously during the period from 1970 to 1977, but there was no way of expressing the changes in quantitative terms. Small sailing boats were replaced by larger motor powered fishing crafts. Nets made of synthetic fiber replaced cotton nets; their length and often their number per each fishing unit increased too. A number of beach-seine units were instructed to change their gear for trammel-nets. Thus, although the total number of fishing units remained more or less constant and limited to 280, the fishing power of each unit in 1977 was estimated to be twice the size of the fishing unit of 1970 (Ben-Tuvia 1979).

After an initial period of biological investigations, the Israeli administration concluded that there was an urgent need for some regulatory measures to conserve the stock of the gilthead bream, the main commercial fish in the Lagoon. The small mesh-size, 34 mm stretched, was retaining young fish, as small as 80 mm T.L. Thus, after a series of mesh-size experiments a 70 mm mesh-size was progressively enforced during the years 1973 and 1974, which releases fish smaller than approximately 180 mm T.L. Simultaneously, this size of fish was established as the minimum legal size for marketing (Ben-Tuvia 1979).

Further studies indicated that a closed fishing season, at least during the winter months, is highly advisable. In November and the first half of December, the adult fish migrate to the sea for spawning and fishing restriction during this period might be beneficial. Less fishing in winter months protects the new-year class which reaches the size of 170-230 mm, and do not leave the Lagoon. The adult fish return to the Lagoon in February after a considerable loss of weight during the period of reproduction in the sea. After two or three weeks of intensive feeding, they resume their normal weight. The fishing in the Lagoon was licensed and the number of fishing units restricted.

These regulations were progressively introduced during the years 1973-1975 and their impacts were so clear in increasing catches during the period 1973-1977.

The Bardawil Lagoon was returned to the Egyptian administration on April 24, 1979. The Ministry of Agriculture; represented by he General

Authority for Fish Resource Development (GAFRD), took over the general management of the lagoon and several regulations were enforced. The destructive gear; beach-seine was prohibited, fishing was forbidden during the winter months; from the beginning of January to early April and the number of purse-seines operating in the lagoon has been decreased. They carried out also maintaining for the two Boughazes in 1986, to dredging and deepening the inlets to about 6 m depth and 500 m width and constructed protecting jetties along the sides of inlets.

Moreover, four cooperative societies were established for about 4130 fishermen working in the lagoon. They provide motors, spare parts, fishing equipment and market the fish for their members who submit their production to the societies.

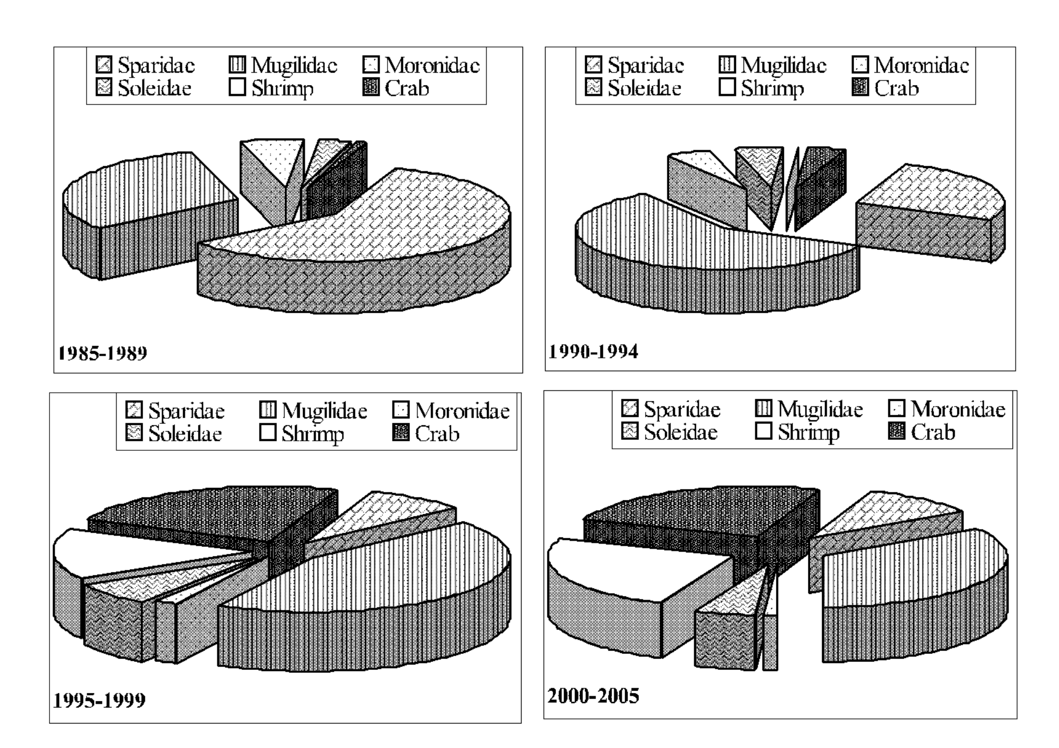
Two fishing gears were introduced to work in the lagoon namely: "Dahbana" and "Bouss". "Dahbana" gear is used mainly to catch *Liza aurata*, so it was named under the fish local name. It is a trammel net similar to the "Dabba" but smaller in mesh sizes (29 mm). "Dahbana" and "Dabba" are used in the same boat.

On the other hand, Mehanna (2006b) mentioned that the catch composition of Bardawil lagoon has changed during the last two decades. Crustaceans (shrimps and crabs) production has greatly increased in the lagoon, reaching about 60 % of the total catch in 2005, affecting the catch of other economic fish species like sea bream and sea bass. During 1980's, *Sparus aurata* constituted about 60 % of the total catch of the lake. This catch decreased to about 15 % of the total fish production in early 1990's and to 8.29% during 2005. This species constituted about 70% of the total landing from the lake during the period from 1969 to 1979 (Ben-Tuvia 1984). The mullets formed about 35% during this period; the moronid species composed about 5.8% in 1980's, then decreased to 3.4% in 1990's and 1.2% in the period 2000-05. Family Soleidae constituted 3%, 4.9% and 4.9% during the same periods. In contrast, shrimps that appeared in the catch during 1995 formed 7.3% in 1990's and 22.9% in 2000-05. In addition, crabs which were recorded in the catch since 1987 formed 0.7%, 13.3% and 23.4% of the total landings (Fig. 9.4).

This serious change in catch composition during the last 20 years can be attributed to a number of factors including the change in the ecological conditions of the lagoon, increasing of fish export and the overexploitation since late 1980's up till now. These factors led to decreasing of sea bream and sea bass production. On the other hand, the appearance and domination of crustacean species could be attributed to the dredging of inlets, which provided suitable environmental conditions that led to flourishing of their stocks and to changing in the fishing procedures in Bardawil Lagoon. Prohibition of purse-

seine fishing technique in 1993 reestablished the sea grass beds in the lagoon, which represent a suitable ecological niche for shrimp (Tom *et al.* 1984). The appearance of crustacean species led to introduction of a new fishing technique to catch them (kalsa fishing technique or trawl nets). This fishing method was very destructive, and contributed in catching fish fry of bottom feeders, like soles, sea bream and sea bass, resulting to progressive decline in their stocks. Moreover, the great change in salinity of the lake gave the chance to several fish species inhabiting Mediterranean coast off Bardawil to find a safe shelter and rich grazing area in the lagoon. For example, several new-recorded species have been appeared and established themselves in the lagoon ecosystem, e.g. *Tilapia zillii*, *Siganus rivulatus* and *Hemiramphus far*. Their production increased from year to year, indicating that they find their suitable habitat in the lagoon.

Fig.9.4. **Catch composition of Bardawil Lagoon during last 20 years (Mehanna 2006).**



9.3 FISHERY STATISTICS

9.3.1 Catch Statistics

Total catch of Bardawil Lagoon during the period from 1958 to 2005 is given in Table 9.2 and Fig. 9.5. The total catch showed a great fluctuation during this period, with a minimum value of 928 tons in the fishing season of 1971 and a maximum value of 3543 tons in 2005. In the period from 1958 to 1966, the lagoon was under the supervision of Mr. Abu Zikri, and the fish production ranged between 1255 tons (1965) and 1719 tons (1966). In the

period from 1967 to 1978, the lagoon was under the Israeli occupation and the production varied from 928 during 1971 to 2658 tons during 1977. From 1979 until present, the lagoon is under the management of the Egyptian General Authority for Fish Resources Development, where the catch varied between 1039 tons during 1979 and 3543 tons during 2005. The fish production of the lagoon increased steadily from 1039 tons to 2784 tons during the fishing season 1982, and then decreased progressively until 1987. After 1987, the total catch fluctuated between increase and decrease, reaching its maximum during 2005. The fishery in Bardawil lagoon is generally seasonal from early April to the end of December; while all fishing activities are prohibited in winter, from January to the end of March. These measures were taken to protect the sea bream and sea bass that are known to leave the lagoon for spawning migration. An investigation of the monthly catches showed that the most productive months are the first three months at the beginning of each fishing season (April, May and June); where about 55% of the lagoon production is harvested in these months.

The productivity (kg/feddan) of Bardawil Lagoon ranged between 9.7 kg/feddan in 1994 and 24.38 kg/feddan in 1999 (Table 9.3). It is clear that the productivity per feddan fluctuated over the years, based on the change in gross production of fish and the water area of the lagoon.

It is worth mentioning that the catch statistics alone are not sufficient to give any indication about the fishery status. They provide an absolute measure for the removal part from the stock by man. Without fishing effort statistics, it will be impossible to describe the impact of fishery on the exploited resources.

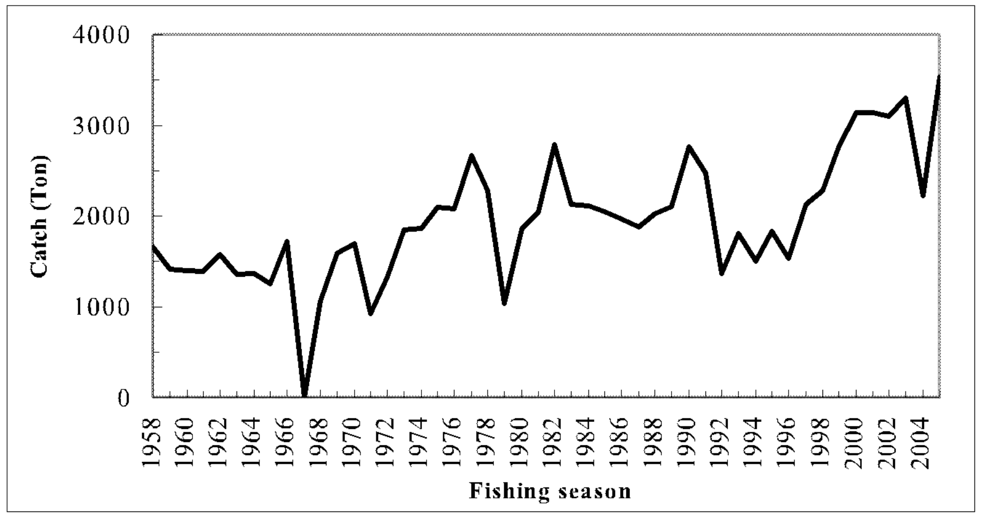


Fig. 9.5. **Fish production of Bardawil Lagoon during the period from 1958 to 2005.**

Year	Catch	Year	Catch	Year	Catch

1958	1656	1974	1861	1990	2762
1959	1416	1975	2095	1991	2472
1960	1401	1976	2081	1992	1371
1961	1394	1977	2658	1993	1810
1962	1574	1978	2276	1994	1500
1963	1360	1979	1039	1995	1832
1964	1368	1980	1854	1996	1536
1965	1255	1981	2049	1997	2128
1966	1719	1982	2784	1998	2277
1967	0	1983	2124	1999	2758
1968	1058	1984	2109	2000	3145
1969	1588	1985	2050	2001	3146
1970	1696	1986	1970	2002	3100
1971	928	1987	1878	2003	3300
1972	1325	1988	2023	2004	2227
1973	1844	1989	2100	2005	3534

Table 9.2. **Annual catch of Bardawil Lagoon (in tons) in the period from 1958 to 2005.**

Table 9.3. **Fish productivity of Bardawil Lagoon during 1988-2005**

Year	Number of fishermen	Productivity	
		Kg/ Feddan	Ton / fisherman
1988	2412	10.30	0.705
1989	2874	13.94	0.800
1990	3678	18.18	0.816
1991	3708	18.18	0.809
1992	3879	10.91	0.464
1993	3950	13.33	0.557
1994	3950	9.70	0.405
1995	3950	13.75	0.557
1996	3950	10.00	0.405
1997	3950	13.75	0.557
1998	3950	11.88	0.481
1999	3950	24.38	0.987
2000	3950	20.60	0.835
2001	3950	19.60	0.796
2002	3950	19.40	0.784
2003	3950	20.60	0.830
2004	3950	13.90	0.563
2005	3950	21.40	0.886

9.3.2 Fishing Effort and Catch Per Unit Effort

The fishing effort operated in Bardawil lagoon during the period from 1980 to 2005 measured by number of fishing days and number of boats showed a great fluctuation. The number of fishing days varied from 130 to 215 days with peaks in 1989, 1993 and 2005. Generally, the numbers of fishing days were regulated to be five days per week. In 2001, the number was reduced to be three days per week, but in the beginning of 2002, they returned to be five days per week. On the other hand, the number of fishing boats is in gradual increase. So, in 1985, 40 Veranda vessels were added to the operating fleet, and in 1993 the number of boats increased by about 123 vessels (67 Dabba and 56 Veranda). This number realized a catch of 1810 tons, but in the following years, the catch

decreased dramatically and the fish stock was depressed with the appearance of crustaceans in 1995. The number of Dabba fishing boats varied from a minimum of 707 boats in 1987 to a maximum of 1176 boats in 2005, while the number of veranda boats fluctuated between a minimum of 8 boats in 1980 and a maximum of 224 boats in 1996. The purse-seiners ranged between 15 and 35 boats during the period from 1980 to 1992. All kinds of fishing boats were standardized according to Dabba to estimate the total fishing effort in the lagoon (Fig. 9.6)

The catch per unit of fishing effort (CPUE) provides an indicator of the relative abundance of the different fish stocks and consequently the status of the fishery. The total catch per unit of fishing effort was estimated as tons per standard fishing boat (Fig. 9.7). The total CPUE varied between a minimum of 0.9 ton/boat during 1992 and a maximum of 2.7 ton/boat during 1982 and after the fishing season 2000, a noticeable decrease in the CPUE was recorded, reflecting the fish abundance in the lagoon during the last six years (Mehanna 2006b).

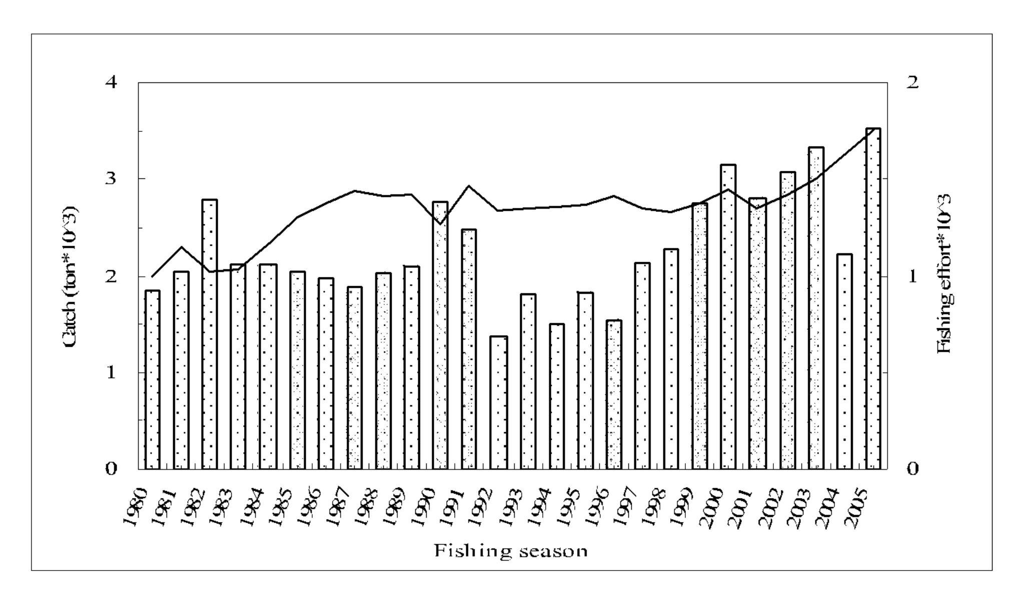
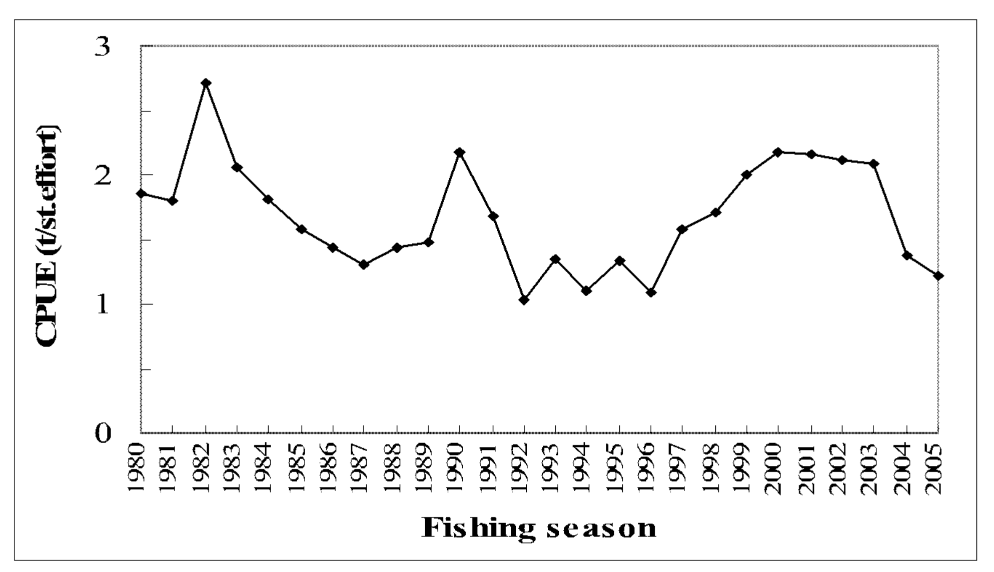


Fig. 9. 6. **Total catch and standard fishing effort at Bardawil Lagoon during the period from 1980 to 2005 (Mehanna 2006b)**

9.3.3 Income

Fishermen depend on the boat production for the amount of fish. New nets and the payments for houses consume up to one third of the income.



Another third is allocated to the motorboat itself, the owner of the boat and other fishermen who are working with him. The total annual revenue in Bardawil Lagoon during the period from 1994 to 2005 is given in Table 9.4.

Fig. 9. 7. **Catch per standard fishing effort of Bardawil Lagoon during 1980-2005.**

Table 9. 4. **Annual catch (in tons) by species and total annual revenue (in LE) in Bardawil Lagoon during the period from 1994 to 2005.**

Fishing season	Breams	Sea bass	Soles	Groupers	Mullets	Crabs	Shrimps	Others	Total catch	Income
1994	75.6	49.4	56.5	7.2	1021	206.2	0	84.2	1500.1	7,736,301
%	5.0	3.3	3.8	0.5	68.1	13.7	0	5.6	100	
1995	110.3	9.8	78.8	5.3	803.9	491.7	273.8	58.6	1832.2	10,842,741
%	6.0	0.5	4.3	0.3	43.9	26.8	14.9	3.3	100	
1996	146.1	26.4	149.4	13.5	916.8	99.4	75.6	109.1	1536.3	11,414,711
%	9.5	1.7	9.7	0.9	59.7	6.5	4.9	7.1	100	
1997	176.4	70.6	138.7	11.9	778.7	506.6	288	157.3	2128.2	15,589,978
%	8.3	3.3	6.5	0.6	36.6	23.8	13.5	7.4	100	
1998	228.4	43.3	134.5	13.8	848.9	552.3	270.9	185.3	2277.5	16,190,491
%	10.0	1.9	5.9	0.6	37.3	24.3	11.9	8.1	100	
1999	139.0	42.6	165.0	9.5	906.3	658.4	576.5	260.8	2758.1	17,856,127
%	5.0	1.5	6.0	0.3	32.9	23.9	20.9	9.5	100	
2000	252.9	31.0	149.2	13.1	953.0	754.2	787.2	204.8	3145.4	22,416,801
%	8.0	1.0	4.7	0.4	30.3	24.0	25.0	6.5	100	
2001	223.1	57.1	141.7	11.2	988.4	520.4	595.2	264.3	2801.3	18,155,280
%	8.0	2.0	5.1	0.4	35.3	18.6	21.2	9.4	100	
2002	266.42	24.7	139.8	11.9	1082.77	608.8	813.4	133.9	3081.7	21,582,112
%	8.64	0.80	4.54	0.39	35.14	19.76	26.39	4.34	100	
2003	279.13	40.1	158.7	12.1	999.76	953.5	808.1	74.31	3325.7	24,623,895
%	8.39	1.21	4.77	0.36	30.06	28.67	24.30	2.23	100	
2004	338.7	26.9	126.7	11.6	703.32	569.7	329.4	120.58	2226.9	17,915,955
%	15.21	1.21	5.69	0.53	31.58	25.58	14.79	5.41	100	
2005	293.0	35.0	168.0	8.0	753.0	1322	775.0	180.0	3534	46,055,200

%	8.29	1.0	4.75	0.23	21.31	37.41	21.73	5.09	100	

The rate of return on capital invested in fishing has been estimated for trammel nets and veranda nets as shown in the Table 9.5 .The rate varies from 9.1% for trammel nets to 15.7% return for veranda nets. In comparison with the opportunity cost of capital, it becomes clear that trammel nets is not economically feasible, but the veranda nets have proved to be economically feasible, and more efficient than the trammel method.

9.3.4 Fishing Gears and Techniques

Table 9.5. **Rate of return on investment in fishing in Lake Bardawil during 1999 (Shaker *et al.* 2000)**

Item	Trammel Nets	Veranda Nets
Capital Costs:		
Fishing Boat	4000	18000
Motor	8000	16000
Fishing Nets	10000	40000
Total Capital Costs	22000	74000
Fishing Period (Days)	150	150
Operating Costs		
Depreciation and Maintenance:		
Fishing Boat	611	2749
Motor	1222	2444
Fishing Nets	2555	10219
Wages	7445	52018
Fuel & Oils	2500	6000
Fish Fodder	1500	8000
Opportunity Cost for the Owner as Manager	1500	12000
Miscellaneous	3000	12000
Total operating costs	20333	105430
Total return	22334	117040
Net return	2001	11600
Rate of return on capital (%)	9.1	15.7

Two main fishing techniques are licensed to operate in Bardawil Lagoon; namely Dabba and Bouss methods. Actually, there are also nine illegal fishing gears that operate in the lagoon in the different months according to the appearance and abundance of the different species.

The Dahbana gear appeared in 1988, as a trammel net that looks like the Dabba gear but well developed. It is used for catching mullets but it is a destructive gear for the sea bream juveniles. In the same year the hand line gear used for catching the sea bass appeared. In 1995, the trawling nets were used for catching shrimps. This gear is very destructive for juveniles of sea beam, groupers and rabbit fishes. It is operating at the beginning of the fishing season (May, June and July), where the sea bream fingerlings are abundant.

Another gear called Cioncholla (looks like Dahbana gear) is working at night for catching *Liza ramada* and *L. aurata*. There is also the Madad gear for catching the groupers and meagers, beside the crabs gear and the Isfinkes gear for catching the soles fingerlings.

- The Dabba fishing technique (Trammel nets)

Dabba fishing vessels (1137 fishing vessels during 2005) constituted about 88.2% of the fishing fleet in the lagoon. Each fishing vessel is about 7m in length and 2 m in width, motorized by outboards of 8 to 10 hp and has two fishermen working on board.

The fishing gear is trammel nets of Italian type; each unit has 30 m average length. The two external layers of the net have 120 mm mesh size and 2 m depth, while the middle layer has smaller mesh size of about 35 mm and about 3 m depth. The fishing gear includes 30 fishing units of trammel net reaching 900 m in length. Each fishing gear is supported by an upper rope that has floating units, separated from each other by about 80 cm, and has a lower rope loaded by parts of lead with an average weight of 50g.

Fishermen spread the net in water in the evening and collect it at the next morning. Catch of these gears is composed of gilthead sea bream *Sparus aurata*, Sea bass *Dicentrarchus labrax, D. punctata*, sole *Solea solea*, grey mullet, *Mugil cephalus*, crab *Portunus pelagicus* and shrimps as *Penaeus japonicus, P. semisulcatus, P. latisulcatus* and *Metapenaeus* spp.

The total production of the Dabba gears or trammel nets reached its maximum value during the fishing season of 2000 (2819 ton) with about 89.6% of the total lagoon production. During 2004, its total production was about 2556 ton.

- The veranda fishing gear or "Bouss"

About 152 fishing vessels of veranda type are engaged in the fishery of the Bardawil Lagoon, constituting about 11.8% of the fishing fleet. The fishing by this technique depends upon groups of 4 vessels working together; two of them motorized by 15-30 hp outboard and the other two are un-motorized and used for carrying nets. 15 fishermen operate each group of vessels. The veranda fishing gear consists of two parts, one horizontal and the other vertical. The vertical part has 600 m in length and 4 m in depth, with 18-20 mm mesh size. It is a single layer net, kept vertically in water by floating pieces of rubber of 40 cm distances between each two successive floaters and loaded at the bottom by pieces of lead, separated from each other by average distances of about 55 cm. The horizontal part is a trammel net, with 600 m in length and 2 m in width, with mesh size of 120 mm for the external two layers and 20 mm for the middle one. The horizontal layer is loaded by units of bamboo supports that keep the

net on the water surface. Each group of vessels has two sets of the fishing gear reaching 1200 m in length.

This fishing gear is used for catching grey mullets only. It depends upon encircling the mullets. Each fishing operation takes about 2 hours and repeated for 4-5 times per day. The total production of the veranda gear during the fishing season of 2001 reached 431.2 ton with an average of 15.4% of the total lagoon production. The revenue of this production was about 3.5 million pounds from 11,890 fishing trips, with an average income of about 293 pound/trip.

- Trawl fishing technique (Kalsa)

The Trawl net (kalsa) is used mainly for fishing crustaceans especially shrimps. It consists of two wings and a bag; the length of each wing is about 10 m (it changes from place to place, according to personal judgment) and its height is about 2 m. The head rope of the wing is fitted with floats; the distance between floats is about 25 cm, while the footrope of the wing is fitted with sinkers of about 25 cm apart.

The bag net is about 9 m in length and 8 mm mesh size. The mouth of the bag net has a radius of about 5 m and the head rope has some floats to keep the bag open, while the foot line of the bag mouth is fitted with weights which keep the bag creeping on the bottom. The net is used by two boats, the fishermen throw the net in water, then the boats move to deeper water where the bag is dragged and finally, the two wings and the bag are pulled to one of the boats to collect the catch.

The catch is composed mainly of shrimps (about 57%), crabs (about 38%) and rabbitfish (about 5%).

- Line fishing technique (Sinnar)

The lines gears operating in the Bardawil Lagoon are long and hand lines. In the long-line method, the mainline is of 300 to 450 m length to which 250 to 300 branch lines are attached. Each branch line has a hook of about 5 to 6cm length. The baits used in this method are small shrimps and grey mullets and the main catch is eels and groupers. In the hand-line, hooks are used individually to catch single fish, while light is used to attract fishes. This method of fishing is operated only to catch the nocturnal fishes and its main catch is *Dicentrarchus labrax* and *D. punctatus*. The boats are used in the two techniques, where each boat has 3 fishermen.

9.4 BIOLOGY AND FIEHERIES OF COMMERCIAL SPECIES

Better understanding of the biology and population dynamics of commercial fish species is a vital step for the rational exploitation of the Bardawil Lagoon. It also constituted the basic input parameters for analytical models used in assessing and managing the lagoon fisheries.

9.4.1 The Sea bream

The Sea bream *Sparus aurata* represents one of the most economic important species in Bardawil Lagoon, as its production was about 48.5% of the total lagoon production (1105.2 tons) in the period from 1962 to 1966. The period from 1982 to 1988 is considered as a stable period, characterized by a relatively constant effort with a good sea bream catch of about 56.5% of the total catch. In the period from 1989 to 1994, the sea bream production was sharply declined from 952 ton in 1989 to 75.6 ton in 1994. From the period from 1995 to 2000, the catch fluctuated between 110.8 and 252.9 tons. The catch slightly increased through 2002-2004 recording 266, 279 and 338.7 tons respectively, and further decreased again to 293 tons in 2005 (Fig. 9.8).

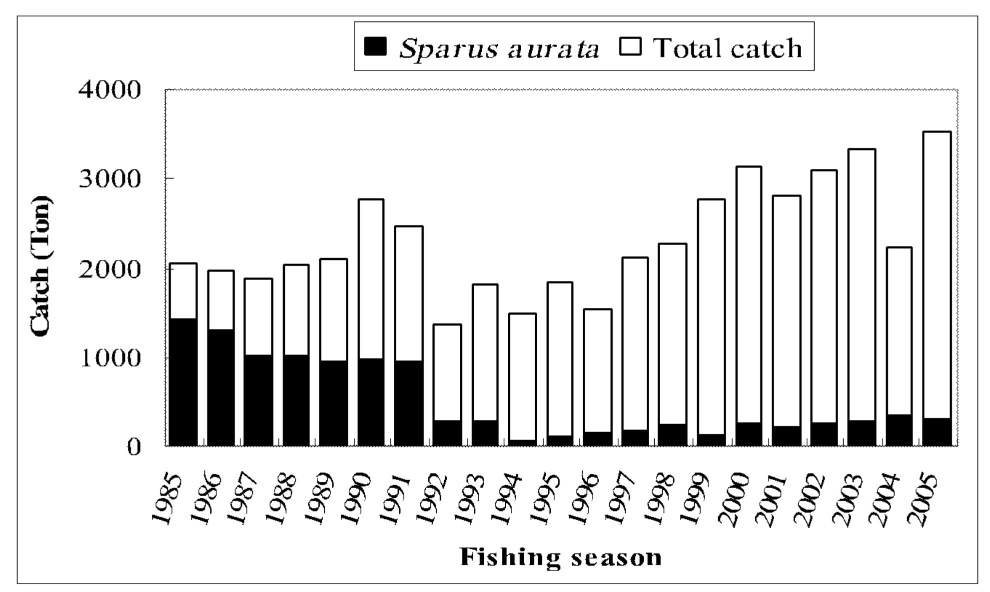


Fig. 9.8. **Gilthead seabream and total catch in Bardawil lagoon during the period from 1985 to2005**

Little work was done on the biology and population dynamics of *S. aurata* in the Bardawil Lagoon. Ben-Tuvia (1979) and Ben-Tuvia & Golani (1979) studied its life history and fisheries biology during the period from 1969 to 1979; Ameran (1992) estimated the population parameters and yield per recruit through two fishing seasons of 1985-1986; Khalifa (1995) focused on fishery statistics, growth and its biological aspects, especially feeding habits, while Fattoh (1996), forecasted its total catch until the year 2000. Tharwat *et al.* (1998) evaluated the status of its stock in the lagoon, as well as yield biomass and maximum sustainable yield per recruit under the different levels of fishing effort.

Ben-Tuvia (1979) and Ben-Tuvia & Golani (1979) found that the catch was composed chiefly of fish of 180–300 mm length, belonging to age groups

of 0–4 yr based on otolith readings. They estimated the length - weight relationship constants as $a = 3.73*10^{-5}$ and $b = 2.81$. They concluded that, under pressure of increase fishing effort, the average size of the sea bream has decreased in the last years.

Table 9.6. **Length-weight relationship of the gilthead sea bream *S. aurata* in Bardawil Lagoon (Tharwat *et al.* 1998).**

Total Length (cm)		No. of Fishes	Total Weight (g)	
Range	Mean		Observed (Mean+SD)	Calculated
14-15	14.5	12	41±4.2	42
15-16	15.7	24	53 ± 4.0	53
16-17	16.8	33	64 ± 6.1	65
17-18	17.4	70	72 ± 6.9	72
18-19	18.5	136	86 ±7.8	87
19-20	19.7	210	104 ±9.2	105
20-21	20.5	336	120 ±9.3	118
21-22	21.5	203	138 ±6.7	137
22-23	22.7	160	159 ± 8.4	161
23-24	23.6	116	180 ±7.9	181
24-25	24.5	73	202±10.5	203
25-26	25.6	62	234±11.2	232
26-27	26.6	31	260 ± 15.0	260
27-28	27.5	21	291 ± 13.4	288
28-29	28.5	18	319±12.5	321
29-30	29.4	10	352±14.3	352
30-31	30.4	11	389 ± 12.1	390
31-32	31.6	6	440±10.6	438
32-33	32.7	3	491 ±11.0	486
33-34	33.5	2	530 ±16.9	523
Total	——	1537	---------	------------——
Average	21.2	--------	131± 1.5	---------

Ameran (1992) determined the longevity of *S. aurata* collected during two fishing seasons (1985-1986) as three years old. He estimated the length – weight relationship as $W = 0.01973\ L^{2.8546}$ and the growth parameters as $L_{\infty} = 38.047$ cm, $K = 0.246$ year^{-1}, $t_o = -1.925$ year.

Khalifa (1995) studied the biology and dynamics of *S. aurata* collected during three successive years (1985-1987) from Bardawil lagoon. He estimated the following length – weight equations:

Males $W = 0.014\ L^{3.008}$
Females $W = 0.007\ L^{3.205}$
Pooled data $W = 0.011\ L^{3.063}$

He also, estimated the composite and relative condition factors (K_c & K_n) as:

Males $K_c = 1.008 \pm 0.0413$, while $K_n = 1.3953 \pm 0.0558$
Females $K_c = 0.9988 \pm 0.0278$, while $K_n = 1.40 \pm 0.0590$

Pooled data K_c = 1.0295 ± 0.0370, while K_n = 1.4024 ± 0.0512

Khalifa (1995) estimated the von Bertalanffy growth parameters of *S. aurata* collected from Bardawil Lagoon during the period from 1985 to 1987 (Figs. 9.7 & 9.8).In contrast to Ameran (1992), who didn't find any difference in growth rate of *S. aurata* during 1985 and 1986, Khalifa (1995) stated that the growth rate of *S. aurata* inhabiting Bardawil lagoon differs from a year to another, where the growth rate during 1985 was less than that of years 1986 and 1987. He attributed this low growth rate during 1985 to the silting up of the inlets and subsequent increase in salinity during year 1984. Thereafter, when the inlets were reopened during 1985, the rates of growth increased during 1986 and 1987. His opinion depends on the work of Ben-Tuvia (1979, 1984 & 1985) and Pisanty (1981), who pointed out that salinity was the most important abiotic factor influencing the ecological processes of the Lagoon and its fishery.

Tharwat *et al.* (1998) observed that the total length of *S. aurata* in the catch of Bardawil Lagoon ranged from 14 to 34 cm with an average of 21.2 cm, while the mean total weight of the fish ranged from 41 to 530 g, with an average of 131 g (Table 9.7). They estimated the longevity to be 5 years, using the scale readings. The increment in total length reached its highest value (18 cm) during the first year of life, then followed by a gradual decrease with age and reaches its minimum value (1.9 cm) at the fifth year of life. The young fish belonging to the first year of life constitute about 29%, while those of two years age represent about 63%. They estimated the length-weight relationship constants as a = 0.0127 and b = 3.0347. They found that the calculated values of the composite coefficient of condition (K_c) were higher than those of relative ones (K_n) and the values of K_c fluctuated between 1.34 and 1.41, while those of K_n ranged from 0.98 to 1.02. The von Bertalanffy (1938) growth parameters in their study were L_∞ = 38.5 cm, K = 0.297 year^{-1}, t_o = -1.085 year and W_∞ = 796.3 g. They also estimated the total, natural and fishing mortality rates as Z = 1.52, M = 0.66 and F = 0.86 year^{-1} respectively. The estimated exploitation ratio (E = F/Z) using these parameters was E = 0.57, which indicates that the stock of the gilthead sea bream in Bardawil Lagoon is slightly overexploited. They recommended reducing F to 0.80 y $^{-1}$ with the increase of t_c to 1.6 year and total length from 20 to 21.2 cm. This will lead to increase MSY / R and reduce the decline of the stock of *S. aurata* especially fish of age group II and allowing them to take part in reproductive cycle. Also, Tharwat *et al.* (1998) in their study noticed that the annual catch and CPUE of *S. aurata* were sharply decreased during 1994 and then gradually increased in the following years (1995 &1996). They attributed this to the overfishing during 1993 and increasing of fishing effort in 1994 by about 39 Dabba vessels. On the other hand, the increase in annual catch during 1995 and 1996 can be attributed to the effect of stopping Chinchólla gear (1992) from fishing inside the lagoon and to the process of development and dredging of Boughazes and silt bottom of the lagoon, allowing great number of recruiting fish to enter the lagoon from the sea.

Table 9.7. **Back-calculated lengths with age of *Sparus aurata* from different localities in Egypt (Mehanna 2006c).**

Locality	Total length at the end of each year of life(cm)						Author
	1	2	3	4	5	6	
Alexandria	17.67	26.16	32.31	39.8	44.11		Wassef (1978)
Bardawil Lagoon							
1969 - 1977	25.15	27.29	28.66	30.05			Ben-Tuvia (1979)
1985	19.50	23.54	26.70				Ameran (1992)
1986	19.70	23.67	26.89				
1985	15.32	19.52	22.69	25.28			Khalifa (1995)
1986	18.36	21.31	23.51				
1987	19.36	23.67	26.29	28.39	--	32.16	
2000	21.44	27.02	30.05	31.88			Abd-Alla 2004
2001	20.97	26.72	30.17	32.19			
Port Said	21.26	27.80	32.25	34.30			Mehanna 2006

Abd-Alla (2004) reported that the total length of *S. aurata* in Bardawil Lagoon varied from 13.6 to 33.5 cm and from 12.6 and 32.8 cm during the fishing seasons 2000 and 2001 respectively, while the total weight ranged between 36.2 and 541 g and between 29 and 514.8 g during 2000 and 2001 respectively. He estimated the longevity as 4 years with age group zero is the most frequent group in the catch. He estimated the length-weight relationship as $W = 0.0134\ L^{3.024}$ (2000) and $W = 0.01378\ L^{3.0167}$ (2001). The von Bertalanffy growth parameters in his study were L_∞= 34.08 cm, K = 0.583 year^{-1}, t_o = -0.702 year (2000) and L_∞= 35.18 cm, K = 0.520 year^{-1}, t_o = -0.742 year (2001). He also estimated the total, natural and fishing mortality rates as Z = 2.5, M = 1.04 and F = 1.46 year^{-1}, respectively (2000) and Z = 2.06, M = 0.98 and F = 1.08 year^{-1} respectively (2001). The estimated exploitation ratio (E = F/Z) using these parameters was E = 0.58 (2000) and E = 0.52 (2001), which indicates that the stock of the gilthead sea bream in Bardawil Lagoon is slightly overexploited.

Tables 9.8 and 9.9 summarized all the available results concerning the back-calculations and growth parameters of *S. aurata* from Egypt.

Table 9.8. **Growth parameters and growth performance index of *Sparus aurata* in Egypt (Mehanna 2006c).**

Locality	L ∞	K	t_o	Ø	Author
Alexandria	70.62*	0.17*	--	2.93*	Wassef (1978)
Bardawil Lagoon					
1985	38.05	0.25	-1.92	2.56*	Ameran (1992)
1986	40.71	0.21	--	2.54*	
1985	34.55	0.24	-1.41	2.46*	Khalifa (1995)
1986	29.96	0.29	-2.23	2.42*	
1987	38.97	0.21	-2.41	2.50*	
1997	38.50	0.30	-1.08	2.65*	Tharwat *et al.*
2000	34.08	0.58	-0.70	2.83*	(1998)
2001	35.18	0.52	-0.74	2.81*	Abd-Alla (2004)
Port Said	37.98	0.50	-0.60	2.86	Mehanna (2006)

Table 9.9. **Length frequency distribution and sex ratio of *Sparus aurata* from Bardawil Lagoon (Tharwat *et al.* 1998).**

Total length (cm)	Number of Fishes			% Male
	Males	Females	Hermaphrodites	
14-15	12	0	0	100.0
15-16	24	0	0	100.0
16-17	30	3	0	90.9
17-18	61	9	1	87.1
18-19	95	41	9	69.9
19-20	120	90	19	57.1
20-21	76	260	23	22.6
21-22	36	167	23	17.7
22-23	25	135	17	15.6
23-24	17	99	22	14.7
24-25	9	64	13	12.3
25-26	5	57	7	8.1
26-27	1	30	2	3.2
27-28	0	21	0	0.0
28-29	0	18	0	0.0
29-30	0	10	0	0.0
30-31	0	11	0	0.0
31-32	0	6	0	0.0
32-33	0	3	0	0.0
33-34	0	2	0	0.0
Total	511	1026	136	
Sex ratio	1 : 2.0			

Reproductive biology

The study of reproductive biology of an exploited fish stock is of a great importance for the assessment of its potentiality as a fishery resource and knowing the time of spawning is essential to protect the ripe females, while the length at first sexual maturity is important for determining the optimum length at first capture and consequently the optimum mesh size. On the other hand, one of the most valuable tools for fisheries management is to ensure the contribution of most individuals in the spawning at least once throughout their life span.

The reproduction of *S. aurata* at Bardawil lagoon takes place in the Mediterranean Sea. All the adult fish, approaching the end of the second year and older, leave the Lagoon in November-December and evidently return to the Lagoon after spawning during the second half of February (Ben-Tuvia 1979; Ben-Tuvia & Golani 1979).

Tharwat *et al.* (1998) investigated the gonads of *S. aurata* and found that the young fishes belonging to length groups of 14-16 cm were males and all fishes greater than 27 cm were females. An overlapping was observed for males and females at total lengths that ranged from 16 to 27 cm. Anatomical investigation of the gonads revealed that 136 fish have both ovarian and

testicular tissues i.e. hermaphrodites. They also estimated the sex ratio between males and females and found to be approximately 1: 2.01 (Table 9.9). This is in accordance with the finding of Ben Tuvia & Herman (1972), who reported that the percentage of females of *S. aurata* in Bardawil Lagoon increased from 61% for age 1 to 75% at age 2 yr, 95% at age 3 yr and 100% at age 4 yr, and this species undergoes sex reversal.

Tharwat *et al.* (1998) determined the length and age at first sexual maturity and found that almost males and females of *S. aurata* attained their first sexual maturity at about 20 cm mean total length, which corresponds to an age of 1.5 year and all examined males and females with total length of more than 24 cm were sexually mature (Table 9.10).

Abd-Alla (2004) estimated the length and age at first maturity for *S. aurata* during 2000 and 2001 as 20.5 cm for males and 21.2 cm for females (2000) and 20.6 cm for males and 22.1 cm for females (2001). These lengths corresponded to ages 0.85 yr for males and 0.95 yr for females (2000) and 0.98 yr for males and 1.17 yr for females (2001).

Table 9.10. **Percentage of mature males and females of *Sparus aurata* (Tharwat *et al.* 1998)**

Total Length (cm)	Males		Females	
	Total No.	% Mature	Total No.	% Mature
14-15	12	0.00	—	—
15-16	24	12.50	—	—
16-17	30	20.00	3	00.00
17-18	61	26.23	9	22.22
18-19	95	35.99	41	34.15
19-20	120	45.83	90	43.33
20-21	76	51.32	260	50.00
21-22	36	69.44	167	65.27
22-23	25	88.00	135	80.00
23-24	17	94.12	99	89.90
24-25	9	100.00	64	100.00
25-26	5	100.00	57	100.00
26-27	1	100.00	30	100.00
27-28	—	—	21	100.00
28-29	~	—	18	100.00
29-30	—	—	10	100.00
30-31	—	—	11	100.00
31-32	—	—	6	100.00
32-33	_	—	3	100.00
33-34	—	—	2	100.00
Total	511		1026	

Food and feeding habits

Khalifa (1995) analyzed stomach contents of 328 *S. aurata* fish; qualitatively and quantitatively using occurrence and points' methods. About 45 species of food material were identified among the food items in the stomachs. Regarding the percentage of occurrence, molluscs, crustaceans, polychaetes, insect larvae, higher plants remains, diatoms and sand grains were most frequent during winter. Echinoderms and green and blue-green algae dominated during summer. Digested matters as well as miscellaneous objects were found in almost all of the examined stomachs all over the year. Food items showed a wide range of feeding habit, but gilthead breams showed a special preference to molluscs, while the rest of food items are ingested accidentally. The results also indicated that this species is benthic feeder.

Previous studies showed that stomach contents of *S. aurata* varied from place to place. In general, it could be concluded that the importance of certain food items for *S. aurata* depends on its availability in their habitat. However, all the studies agreed in that *S. aurata* is a carnivorous fish species. Meanwhile, Ishak *et al.* (1980) found that algae and zooplankton are the main food items in the stomachs of gilthead sea bream in Lake Qarun, Egypt. This coincides with the conclusion of Wassef (1978) and Wassef & Eisawy (1985) who stated that when a certain food item or group became scarce, gilthead sea bream turned to many alternative food resources.

9.4.2 Mullet species

Mullet species are considered as one of the most valuable fish resources at Bardawil lagoon, where they contribute about 38.5% of the total lagoon production (1985-2005). Their catch fluctuated greatly with a minimum of 351 tons during 1985 and a maximum of about 1408 tons during 1990. The total mullets catch in Bardawil Lagoon shows a general trend of decline in spite of the general increase in fishing effort. The mullet species composed the bulk of lagoon catch during 1994, contributing about 72% of the total lagoon production. This percentage gradually decreased in the following years to be 43.9 % in 1995, 36.6% in 1997, 31.6% in 2004, then decreased sharply to 21% during 2005 (Fig. 9.9).

The species composition of the mullets in the lagoon catch is composed of six species; *Mugil cephalus, Liza ramada, Liza aurata, Liza saliens, Chelon labrosus* and *Liza carinata* of which *Mugil cephalus* is the most abundant species, contributing more than 50% of the mullets catch. Mullets are fished by Veranda or Bouss fishing method in the lagoon.

The longevity and von Bertalanffy growth parameters of five mullet species collected from Bardawil Lagoon during the fishing season 1985 were estimated by Bebars *et al.* (1986) and given in Table 9.11. It is clear that *M. cephalus* has the longest life span with maximum length of about 75 cm. The

maximum life span of *M. cephalus* was estimated as five years for females and three years for males, while that of *Liza ramada* was found to be four years for both sexes. They over-estimated the longevity for *L. aurata* as five years and for *L. saliens* as three years for males and four years for females. The unsexed *Chelon labrosus* was found to be four years old. The back-calculated lengths recorded for *M. cephalus* in their study were 29.01, 43.03, 54.32, 61.59 and 66.27 cm for females and 27.36, 36.84 and 42.99 cm for males respectively. They also estimated the length-weight relationship for *M. cephalus* in Bardawil Lagoon as W = 0.0182 L2.8174.

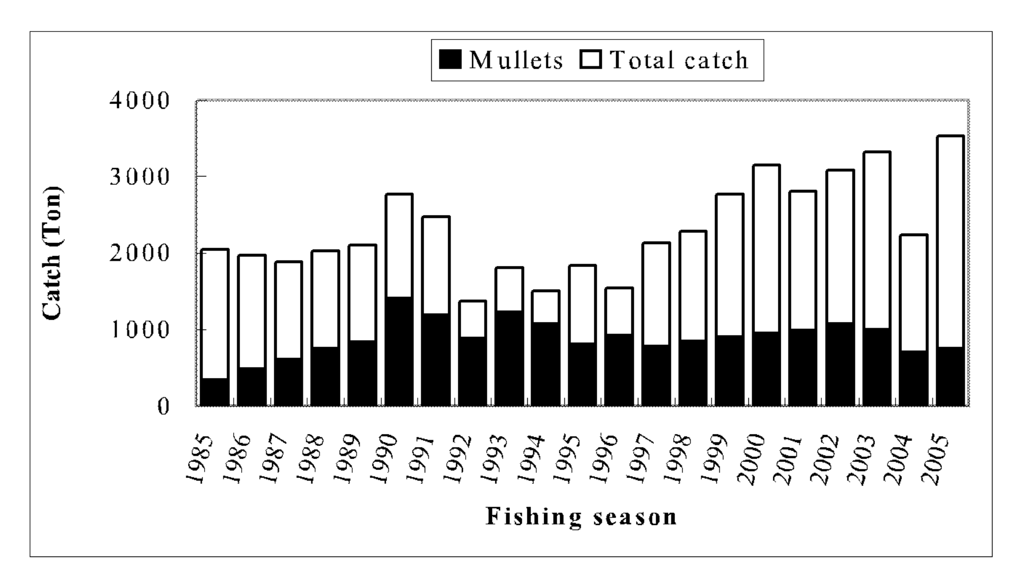


Fig. 9.9. **Mullets and total catch in Bardawil Lagoon during the period from 1985 to 2005.**

Table 9.11. **Growth parameters and longevity of the mullet species in Bardawil Lagoon (Bebars *et al.* 1986).**

Species	L_∞	K	t_0	W_∞	Longevity (Yr)
Mugil cephalus	M 54.3 F 79.22	0.433 0.341	-0.618 -0.337	1406 4091	3 5
Liza ramada	M 46.23 F 54.84	0.396 0.316	-0.548 -0.575	790 1298	4 4
Liza aurata	M 39.42 F 37.02	0.247 0.287	-1.397 -1.191	486 412	5 5
Liza saliens	M 28.43 F 33.8	0.389 0.303	-0.994 -1.031	179 307	3 4
Chelon labrosus	31.07	0.397	-1.018	276	4

El-Ganainy (2002) analyzed the length frequency distribution of *M. cephalus* in four successive fishing seasons from may 1995 to November 1998 and showed that the small lengths; ≤16.0 cm appear in June and July, indicating that recruitment to the fishery occurs through these months. They estimated the relation between the total fish length and the anterior scale radius for 585 specimens, ranging in total length from 14.0 to 64.0 cm. The resultant equation was represented as $L = 6.2381+2.21338\ S$, where L is the total fish length in cm and S is the scale radius in mm. They also found that the maximum age for the samples of 1995 to 1997 was 6 years old and for the samples of 1998 was 5 years old. The mean lengths at 1997 and 1998 appeared to be smaller due to the increase of the frequencies of the small size classes. The estimated growth parameters of these four fishing seasons showed that the $L\infty$ estimates are in gradual decrease (74.2 in 1995, 73.6 in 1996, 70.4 in 1997 and 64.1 cm in 1998) recording its minimum value in 1998.This could be an indication of growth and recruitment over-fishing.

On the other hand, Mehanna (2006a) studied the population dynamics of *Liza ramada* and *L. aurata* in Lake Bardawil for samples collected during the period from April to December 2004, to assess their stocks and to develop an appropriate management plan to maintain these valuable fishes.

She found that the longevity of *L. ramada* and *L. aurata* extends to five and three years respectively, with their respective age groups II and I being the most frequent (Fig. 9.10). The back – calculated lengths at the end of each year of life were 21.09, 30.05, 36.33, 39.26 and 41.08 cm for 1st to 5th year of life for *L. ramada* and 18.77, 25.59 and 29.31 cm for 1st to 3rd year of life for *L. aurata* respectively. Age readings indicated that both species attain their highest growth rate in length during the first year of life, after which a gradual decrease in growth increment was observed with further increase in age (Table 9.12). The estimated lengths at different ages of the two species in different Egyptian water bodies are summarized in Table (9.13).

Table 9.12. **Back-calculated lengths (cm) at the end of different years of life of *Liza ramada* and *Liza aurata* from Lake Bardawil (Mehanna 2006a).**

Age group (yr)	*Liza ramada*						*Liza aurata*			
	Observed length	**1**	**2**	**3**	**4**	**5**	**Observed length**	**1**	**2**	**3**
I	21.92	**21.09**					19.49	**18.77**		
II	30.86	20.92	**30.05**				26.25	18.59	**25.59**	
III	36.95	20.94	29.88	**36.33**			29.89	18.55	25.44	**29.31**
IV	39.91	20.81	29.76	36.25	**39.26**					
V	41.55	20.73	29.71	36.16	39.11	**41.08**				
Incr.		21.09	8.96	6.28	2.93	1.82		18.77	6.82	3.72
%		51.34	21.81	15.29	7.13	4.43		64.04	23.27	12.69

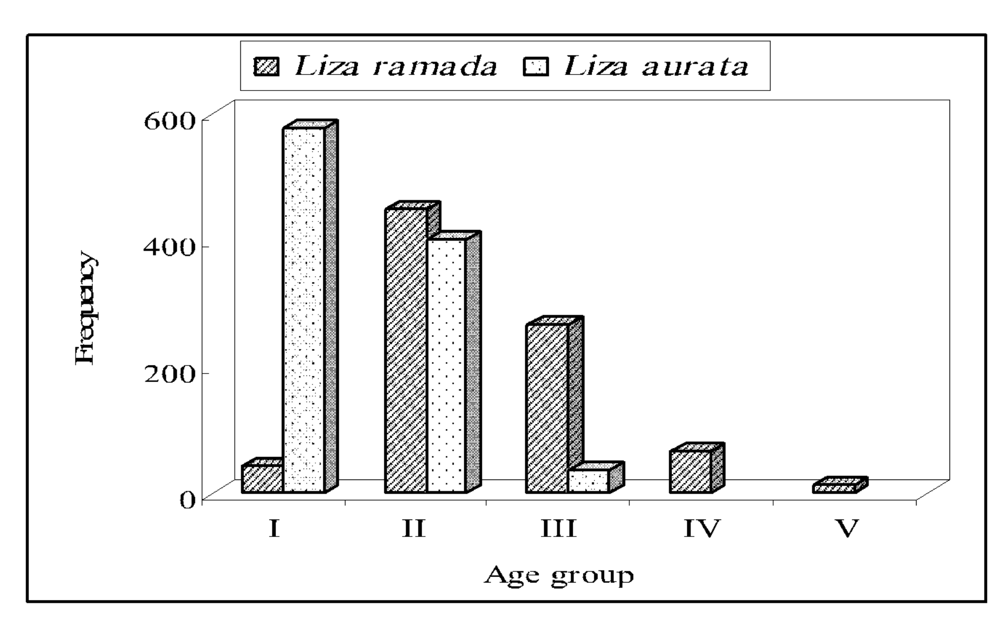


Fig. 9.10. **Age composition of *Liza ramada* and *L. aurata* from Lake Bardawil.**

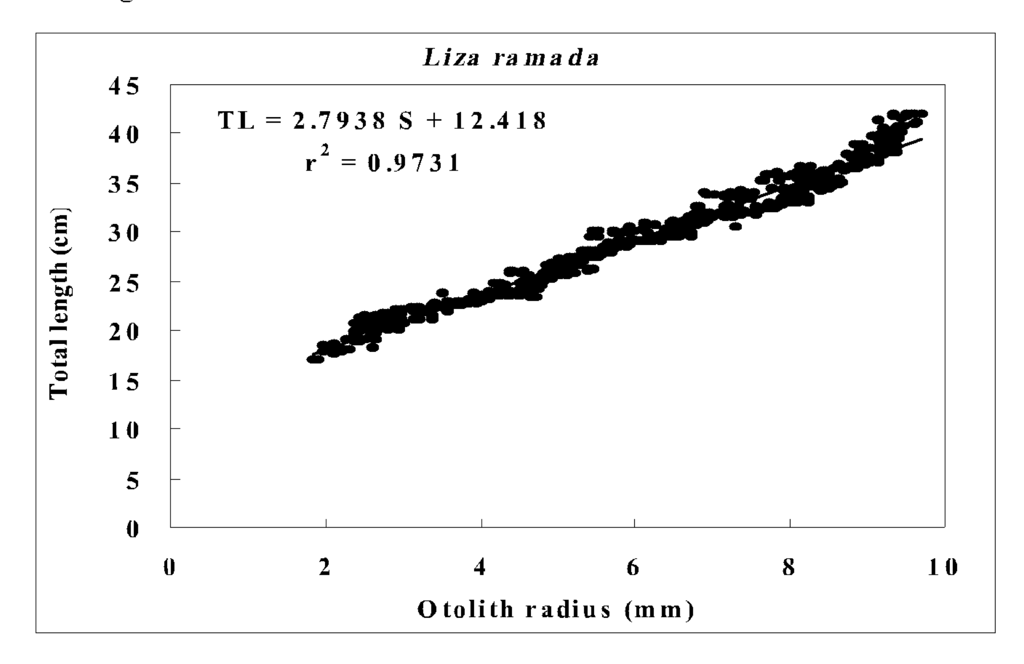
Table 9.13. **Lengths (cm) at different ages for *Liza ramada* and *L. aurata* from some Egyptian water bodies (Mehanna 2006a).**

Locality	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	Author
Liza ramada									
Medit. Coast	14.7	23.8	31.4	37.7	41.7	46.2			Rafail (1968)
Nozha hydrod.									Hashem *et al.* (1977)
Male	16.8	24.2	33.2	--					
Female	18.1	26.8	36.4	44.5					
Lake Timsah									Salem & Mohammed (1982)
Male	19.4	23.0	25.0	--	--	--			
Female	21.6	25.4	29.9	32.1	34.9	41.8			
Lake Burullus	12.8	17.5	23.1	29.0	32.0	34.7			Hosny & Hashem (1995)
Wadi El-Rayan	20.1	28.6	34.6	39.1	42.9	45.8	47.8	48.9	El-Gammal & Mehanna (2004)
Lake Timsah	19.9	29.2	35.5	38.9	41.1				Mehanna & Amin (2005)
Lake Bardawil	21.1	30.1	36.3	39.3	41.1				Mehanna (2006a)
Liza aurata									
Lake Burullus	15.0	24.0							Hashem *et al.* (1973)
Bitter Lakes	17.9	24.9	28.5						Mehanna (2004)
Lake Bardawil	18.8	25.6	29.3						Mehanna (2006a)

She also estimated the total length (L)-otolith radius (S) relationship (Fig. 9.11) as L = 2.7938 S+ 12.418 for *L. ramada* and L = 4.1987 S+ 9.0247 for *L. aurata*., while the length-weight relationship was estimated as $W = 0.0052\ L^{3.134}$ for *L. ramada* and $W = 0.0086\ L^{2.9356}$ for *L. aurata* (Fig. 9.12).

An isometric growth was observed for both species, where the confidence interval CI was 3.191 – 3.078 for *L. ramada* and 2.887 – 2.993 for *L. aurata*. It was found that growth in weight is very slow during the first year and thereafter growth in weight increases with age until it reached its maximum value at age

group III for *L. ramada* and age group II for *L. aurata*. Based on annual increase in weight, it would be economically important to protect the fish till their third year of life for *L. ramada* and second year of life for *L. aurata,* to reach a good marketable size.



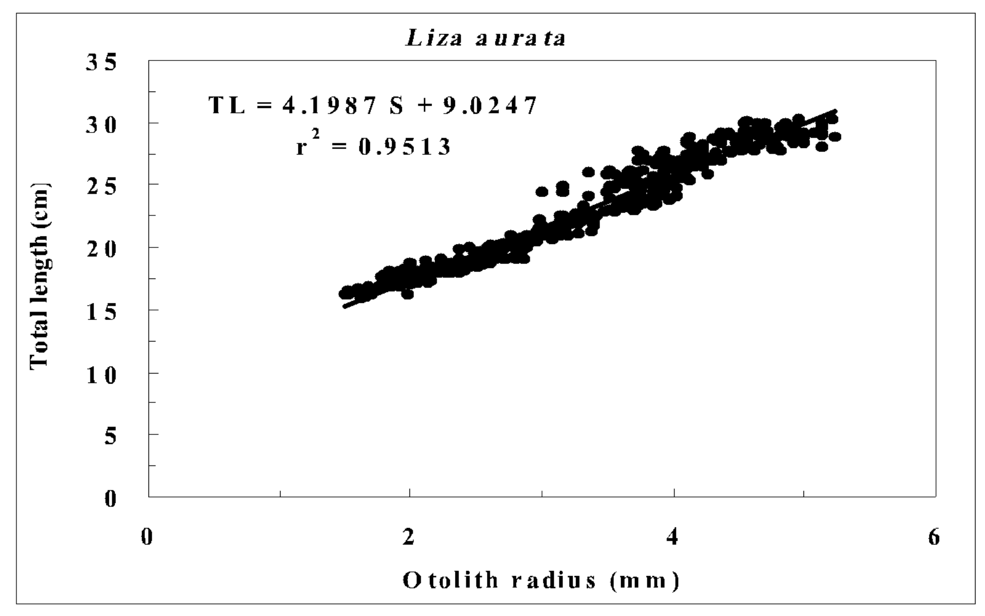
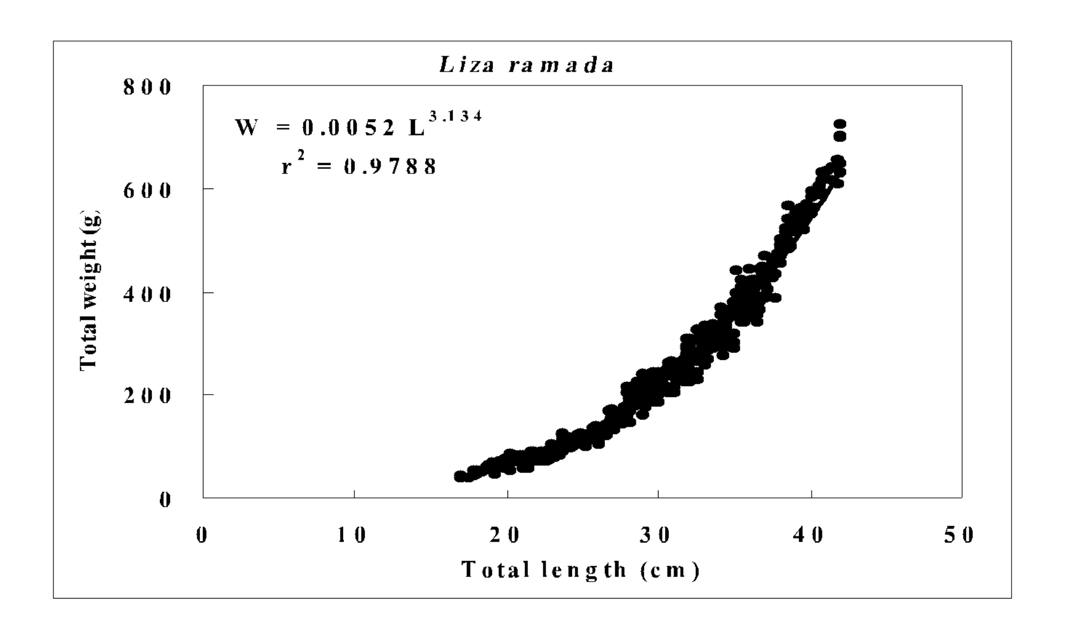


Fig. 9.11. **Total length-otolith radius relationship of *Liza ramada* and *L. aurata* from Lake Bardawil (Mehanna 2006a).**



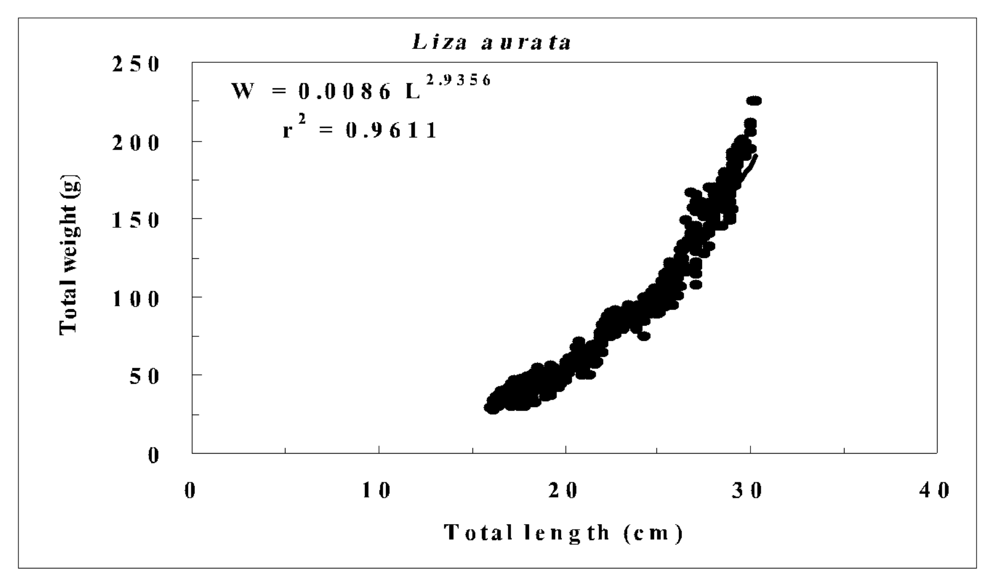


Fig. 9.12. **Lngth-weight relationship of *Liza ramada* and *L. aurata* from Lake Bardawil (Mehanna 2006a).**

The constants of the von Bertalanffy's growth model were represented by the following equations:

L. ramada

For growth in length $L_t = 44.14\ (1 - e^{-0.51(t+0.29)})$

For growth in weight $W_t = 742.86\ (1 - e^{-0.51\ (t+0.29)})^{3.134}$

L. aurata

For growth in length $L_t = 33.77 (1 - e^{-0.61 (t+0.34)})$

For growth in weight $W_t = 264.03 (1 - e^{-0.61 (t+0.34)})^{2.9356}$

The values of growth performance index of *L. ramada* and *L. aurata* were 3.00 and 2.84 respectively. The ø values obtained were consistent with other estimates. It was found that ø = 2.66 for *L. ramada* in Lake Burullus, 2.91 at Wadi El-Raiyan lakes and 2.98 in Lake Timsah. Based on the calculated growth performance index, the growth rate of *L. ramada* in Lake Bardawil was slightly higher than that in the other three lakes. Also, the same trend was observed for *L. aurata* (the growth performance index was 2.82 in Bitter Lakes).

Mehanna (2006a) estimated the total, natural and fishing mortality coefficients (Z, M and F) as 1.22, 0.16 and 1.06 $year^{-1}$, respectively for *L. ramada*. The same parameters were estimated as 1.36, 0.22 and 1.14 $year^{-1}$ respectively for *L. aurata*. The exploitation rate (E) was estimated as 0.87 and 0.84 $year^{-1}$ for both species respectively. The current estimated fishing mortality and exploitation rates for both species were relatively high, indicating a high level of exploitation.

***Table 9.14.* Population parameters for *Liza ramada* and *L. aurata* from Lake Bardawil (Mehanna 2006a).**

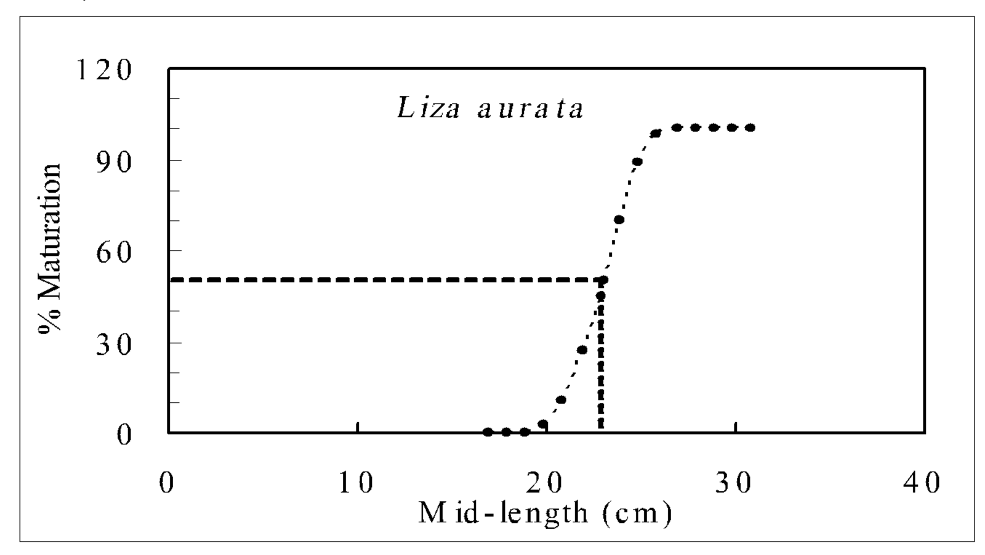
Population parameters	*Liza ramada*	*Liza aurata*
K $year^{-1}$	0.51	0.61
L_∞ cm	44.14	33.77
W_∞ g	742.86	264.03
t_0 year	-0.29	-0.34
ø	3.00	2.84
Z $year^{-1}$	1.22	1.36
M $year^{-1}$	0.16	0.22
F $year^{-1}$	1.06	1.14
E $year^{-1}$	0.87	0.84
L_c cm	18.45	16.92
E_{max}	0.64	0.66
$E_{0.1}$	0.56	0.60
$E_{0.5}$	0.40	0.40

Reproductive biology

Mullets species in Bardawil Lagoon are winter spawners, with a spawning season mainly from late October to early March, with a peak in December. All the ripe fish leave the Lagoon in late summer and autumn to the sea and evidently return to the lagoon after spawning during the late winter and early spring.

The size at 50% maturity for *L. ramada* and *L. aurata* was estimated at 28.71 and 23.11 cm TL respectively (Fig. 9.13) that is equivalent to an age of

about 1.77 and 1.55 years, respectively. The smallest length recorded in the catch L_r was 16.9 and 16 cm for *L. ramada* and *L. aurata*, respectively, which were smaller than the L_{50} and the length at first capture was smaller than L_{50}. This means that the exploited stocks of *L. ramada* and *L. aurata* should be protected in order to have at least once of the spawning activity (Mehanna 2006a).



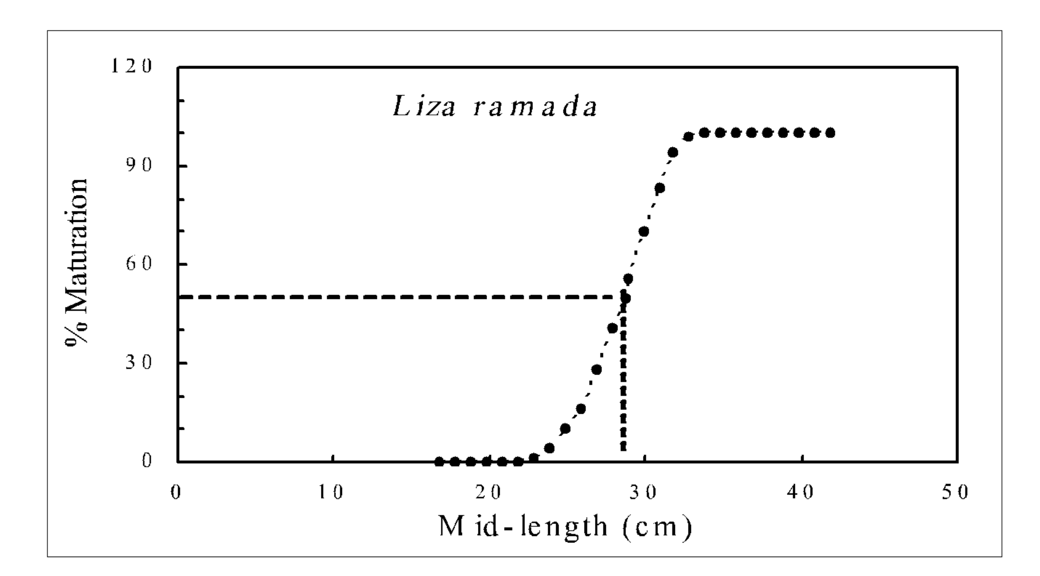


***Fig. 9.13*. Length at first sexual maturity of *Liza ramada* and *L. aurata* from Lake Bardawil (Mehanna 2006a).**

Per-recruit analysis

The relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for *L. ramada* (Fig. 9.14) showed that the maximum (Y'/R) was obtained at E_{MSY} = 0.64. The values of both $E_{0.1}$ (the level of exploitation at which the marginal increase in yield per recruit reached 1/10 of the marginal increase computed at a very low value of E) and $E_{0.5}$ (the exploitation level which resulted in a reduction of the unexploited biomass by 50%) were also estimated. The obtained values of $E_{0.1}$ and $E_{0.5}$ were 0.56 and 0.4 respectively. The results indicate that the present level of E (0.87) is higher than that gives the maximum (Y'/R). The results show also that, the present level of exploitation rate is higher than the exploitation rate ($E_{0.5}$) which maintains 50% of the stock biomass.

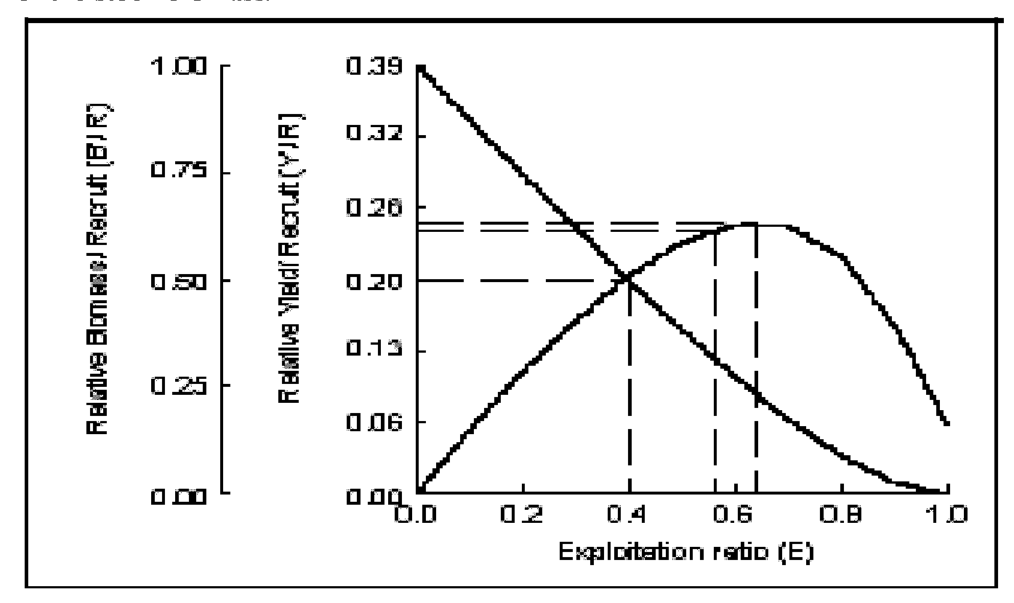


***Fig. 9.14.* Per-recruit analysis of *Liza ramada* from Lake Bardawil (Mehanna 2006a).**

For *L. aurata* (Fig. 9.15), a maximum (Y'/R) can be obtained at E_{max} = 0.66. The values of $E_{0.1}$ and $E_{0.5}$ were 0. 6 and 0.4 respectively. This means that, the exploitation rate of *L. aurata* should be reduced from 0.84 to 0.4 (52.4%) to maintain a sufficient spawning biomass.

Mehanna (2006a) determined the most appropriate length at first capture for *L. ramada* and *L. aurata* at Lake Bardawil through estimating the relative yield-per-recruit, using different values of Lc (25 and 30 cm for *L. ramada* and 20 and 25 cm for *L. aurata*). The results (Figs. 9.16 & 9.17) indicated that with increasing Lc, a higher (Y'/R) can be obtained. For *L. ramada*, when we use Lc = 25 and 30 cm, the maximum (Y'/R) was obtained at E= 0.71 and 0.76 (still less than the current E) respectively. This means that, the present level of Lc is not the optimum for this fish species and it must be increased to 30 cm. The values obtained for $E_{0.5}$ were 0.42 and 0.44 for Lc = 25 and 30 cm respectively.

The same trend was observed for *L. aurata*, when Lc increased to 20 and 25 cm, the maximum (Y'/R) was obtained at E= 0.71 and 0.80 (less than the current E) respectively. The values obtained for $E_{0.5}$ were 0.42 and 0.45 for Lc = 20 and 25 cm respectively. Mehanna (2006a) showed that the stocks of L. *ramada* and *L. aurata* in Lake Bardawil are overexploited. For the management purpose, the current exploitation rate must be reduced from 0.87 to 0.4 (54%), to maintain a sufficient spawning biomass and the length at first capture should be raised from 18.45 to about 30 cm for *L. ramada* and the current E must be reduced from 0.84 to 0.4 (52.4%), while the present Lc should be increased to about 25 cm for *L. aurata*. The main management problem facing the fisheries development in Lake Bardawil, especially mullets is over-exploitation, due to the high fishing pressure, destructive and illegal fishing and mesh size methods, and lack of information on fishery status in terms of biological, ecological, social and economic policy. So, fishery management plan in Lake Bardawil should include:

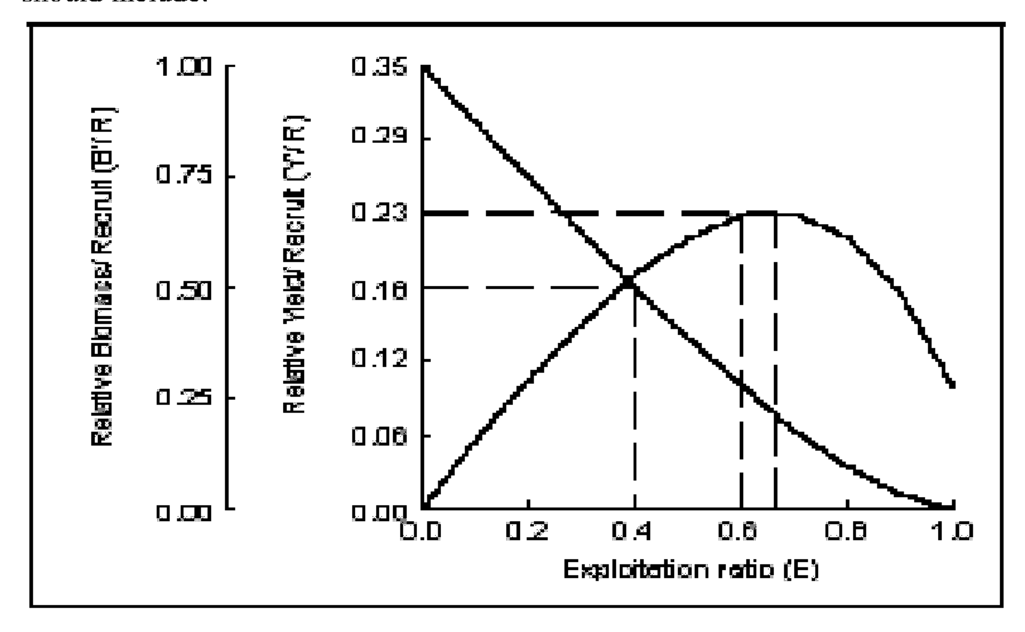


***Fig. 9.15.* Per recruit analysis of *L. aurata* from Lake Bardawil (Mehanna 2006a).**

- Controlling mesh size of nets used and prohibition of the destructive gears.
-Re-evaluating the time of closed season to conserve the spawning stock biomass of mullets during their spawning migration from and to the lake.
- Setting of a total allowable catch.

Preparing an accurate data base about Lake Fishery, involving good records for fishery statistics to facilitate the evaluation and management of this valuable fish resource.

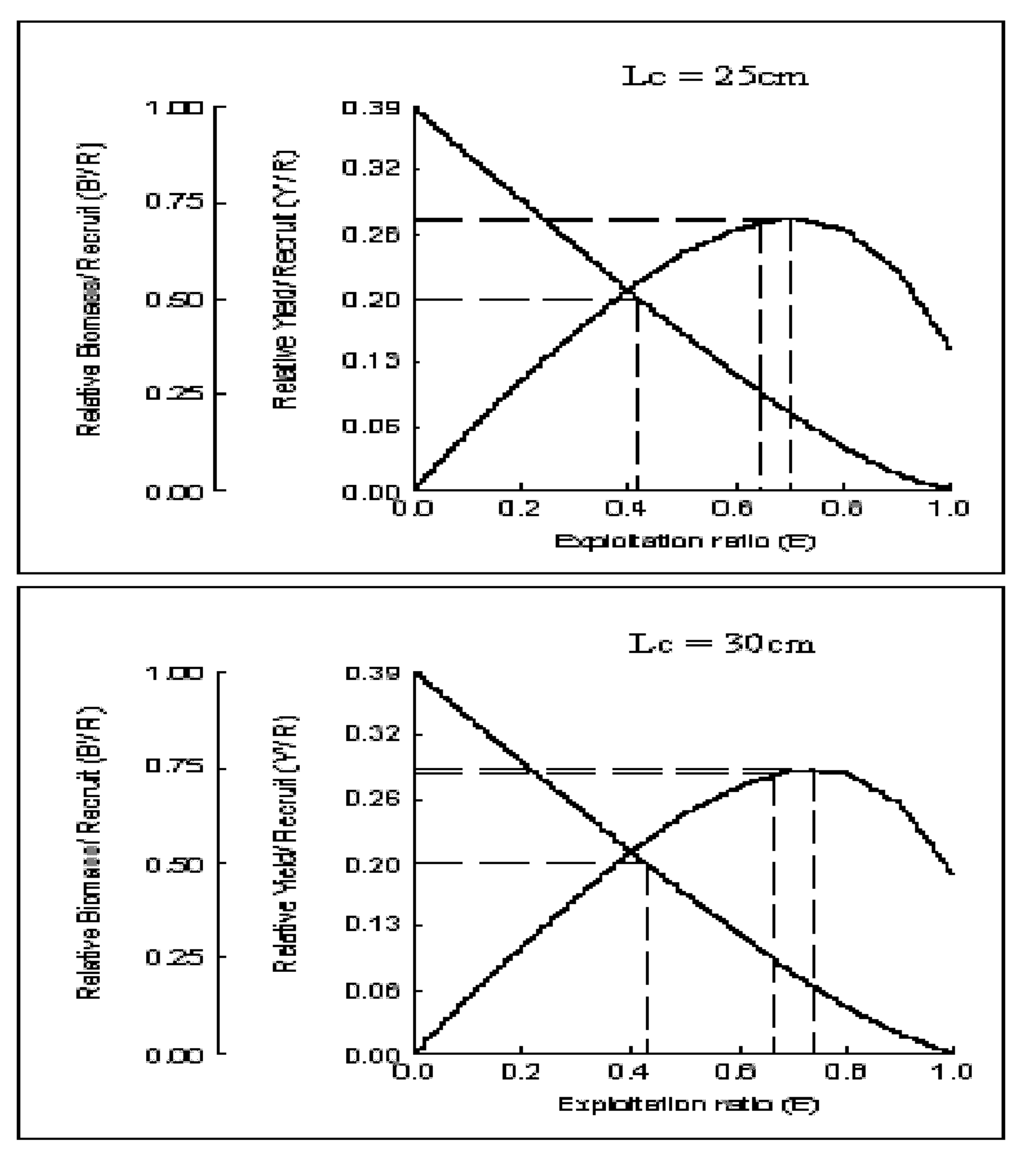


Fig. 9.16. **Per-recruit analysis of *L. ramada* from Lake Bardawil with different values of L_c (Mehanna 2006a).**

9. 4. 3 Flatfishes

The flatfishes (family: Soleidae) constituted about 5.5% of the total fish production from the lagoon (1980-2005). The catch mainly is *Solea solea* and *S. aegyptiaca,* that varied between a minimum of 13 tons during 1985 and a maximum of 165 tons during 2005 with a mean of 109.5 tons (Mehanna 2006b). Soles' catch showed a gradual increase from 1985 reaching 101.3 tons in 1988 then decreased to 94.4 tons in 1989. In 1992, 1994 and 1995, a dramatic decline in soles' catch was recorded (61.8, 56.6 and 78.9 tons respectively). From 1996

to 2005, the soles catch did not show a great variation and fluctuated between 126.7 and 168 tons (Fig. 9.18).

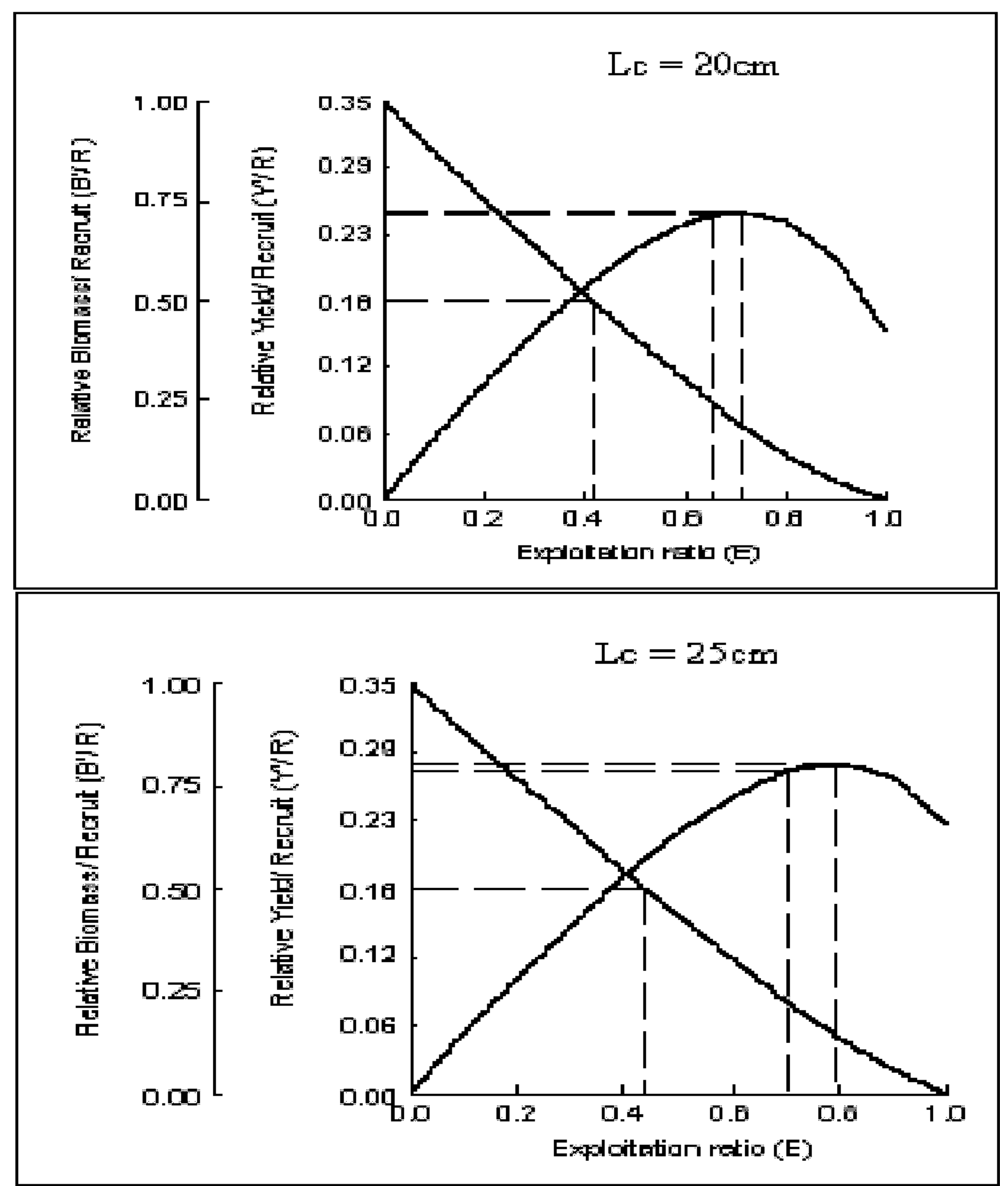


Fig. 9.17. **Per-recruit analysis of *L. aurata* from Lake Bardawil with different values of L_c (Mehanna 2006a).**

The population dynamics of flatfishes at Bardawil Lagoon was only studied by El-Gammal *et al.* (1994). They studied the age and growth, mortality and exploitation rates, yield per recruit of *Solea solea* that collected during the fishing season of 1987.

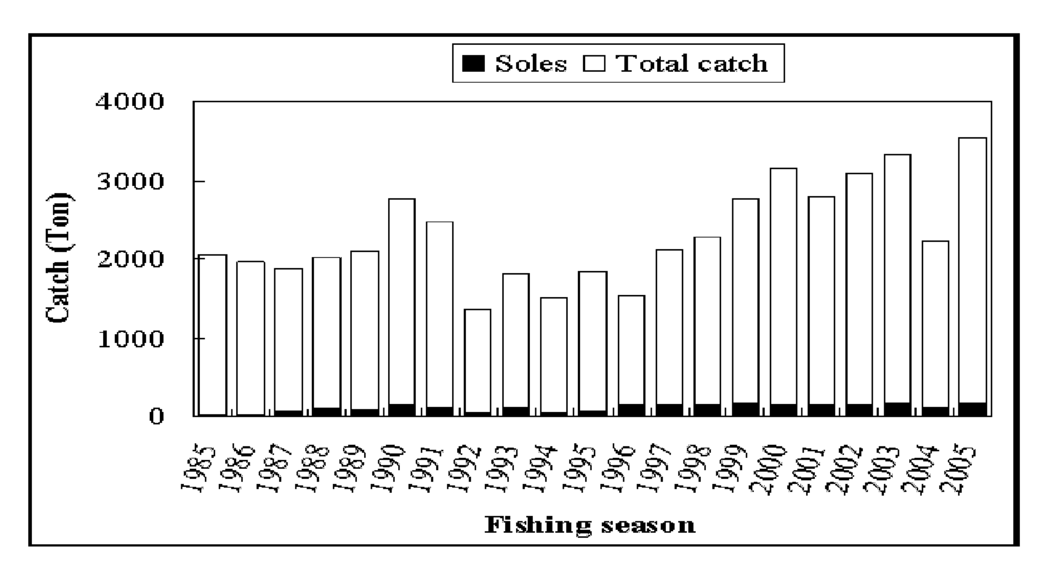


Fig. 9.18. **Soles and total catch in Bardawil Lagoon during the period from 1985 to 2005.**

They found that the length frequency distribution of *S. solea* ranged between 15 and 24.9 cm for males and between 15 and 28.9 cm for females (Table 9.15). They determined the maximum life span of males as four years and that of females as six years. The age group II was the most abundant in the catch, indicating that the soles individuals are fully recruited to the fishery at age group II. The estimated growth parameters of pooled data of *S. solea* were L_∞ =30.06 cm, K = 0.336 year^{-1} and t_o = -1.509 year (Table 9.16). The estimated mortality coefficients were Z (total mortality) = 1.266, M (natural mortality) = 0.212 and F (fishing mortality) = 1.054 year^{-1}. The corresponding exploitation ratio (E =F/Z) was 0.83, which an obvious indication of overexploitation.

Table 9.15. **Length frequency distribution of *Solea solea* from Lake Bardawil during 1987 (El-Gammal *et al.* 1994).**

Length groups	Males		Females		Sexes combined	
	No.	%	No.	%	No.	%
15 - 15.9			2	0.39	7	0.96
16 – 16.9			5	0.96	12	1.64
17 – 17.9	5	2.36	10	1.93	16	2.19
18 – 18.9	7	3.30	10	1.93	26	3.56
19 – 19.9	6	2.83	25	4.81	41	5.61
20 – 20.9	16	7.55	68	13.10	99	13.54
21 – 21.9	16	7.55	105	20.23	157	21.48
22 – 22.9	31	14.62	108	20.81	151	20.66
23 – 23.9	52	24.53	76	14.64	96	13.13
24 – 24.9	43	20.28	55	10.60	69	9.44
25 – 25.9	20	9.43	33	6.36	35	7.78
26 – 26.9	16	7.55	14	2.70	14	1.92
27 – 27.9			5	0.96	5	0.68
28 – 28.9			3	0.58	3	0.41
Total	212	100	519	100	731	100

Table 9.16. **The von Bertalanffy growth parameters of *Solea solea* from Lake Bardawil during 1987 (El-Gammal *et al.* 1994).**

Method of:	Sex	L_∞ (TL)	K yr^{-1}	t_o yr	W_∞ (g)
Ford – Walford	Males	26.29	0.497	-1.143	161.37
	Females	30.22	0.330	-1.529	263.36
	Pooled	30.04	0.336	-1.519	254.03
Gulland & Holt	Males	26.29	0.487	-1.217	161.37
	Females	30.22	0.323	-1.636	263.36
	Pooled	30.05	0.333	-1.559	254.29
Chapman	Males	26.31	0.495	-1.148	161.75
	Females	30.22	0.323	-1.636	263.36
	Pooled	30.06	0.336	-1.509	254.55

Table 9.17. **The estimated growth parameters of *Solea* spp. in Egyptian waters (Mehanna 2005).**

Locality /species	K (yr^{-1})	L_∞ (TL)	Ø	M	Age (yr)	Author
Lake Bardawil *S. solea*	0.336	30.06		2.212	6	El-Gammal *et al.* (1994)
Port Said *S. aegyptiaca*	0.53	30.9	2.7	0.75	4	Mehanna (2005)

El-Gammal *et al.* (1994) studied also the effect of fishing mortality on the yield per recruit of *S. solea* at Bardawil lagoon and found that the maximum Y/R was obtained at F = 1.0, which is less than the present value. They used different values for age at first capture to estimate Y/R and to detect the optimum mesh size for this species. They concluded that *S. solea* stock suffers from overexploitation and the fishing effort should be decreased to maintain this resource as well as the age at first capture increased.

Reproductive biology

Reproduction of *Solea* spp. takes place in the lagoon, while the spawning season extends from late March to the end of May, with a peak in April. Each ripe female can produce about million eggs annually.

Food and feeding habits

Soles species in Bardawil lagoon feeding on worms, small crustaceans, molluscs and fish scales. They are nocturnal, feeding mainly at night.

9.4.4 The Sea bass

The European sea bass *Dicentrarchus labrax* is one of the important fishes in Bardawil Lagoon. Since early 1990's, the catch of this species has dramatically declined because of irrational management strategy and uncontrolled fish export policy in the lagoon (Fig. 9.19). The sea bass catch has greatly fluctuated during the period from 1985 to 2005, with a minimum value of 9.8 ton during 1995 and a maximum value of 185.9 ton during 1990

contributing about 1.2% of the total lagoon production during this period. In late 1980's and early 1990's, sea bass was exported to Europe and its production during this period constituted about 16% of the total lagoon production. The maximum value for exported sea bass was recorded during 1991 (about 157.3 ton). From 1995 onward, sea bass production shows a steady decline, recording 35 ton during 2005. Sea bass is exploited by two fishing methods in the lagoon; trammel nets and lines. The length frequency of sea bass caught by trammel nets is smaller than that of lines, where the length of sea bass fished by trammel nets ranged between 17 and 32 cm TL and that fished by hook and lines ranged between 25 and 67 cm TL, but the number of fish that attained lengths greater than 50 cm TL was very limited.

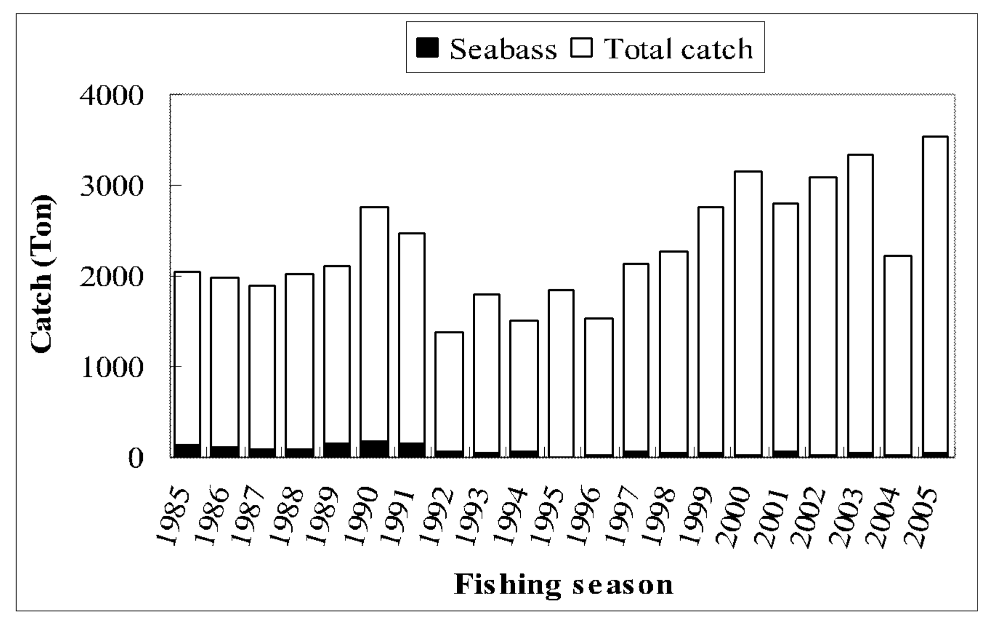


Fig. 9.19. **Seabass and total catch of Bardawil Lagoon during the period from 1985 to 2005**

Anonymous (1986) pointed out that the maximum life span of *D. labrax* was two years for males and six years for females. The back calculated lengths at the end of each age group were 22.67 and 27.61 cm for males and 23.65, 41.28, 54.31, 63.62, 70.15 and 74 cm for females respectively. Also, they estimated the von Bertalanffy growth parameters as $L\infty$ = 86.66 cm and K = 0.33 year^{-1}.

Hegazy & Sabry (2001) recorded seven age groups for *D. labrax* at Bardawil and gave lengths of 16.1, 30.8, 42.5, 51.7, 59.1, 64.9 and 69.6 cm for these age groups respectively. They estimated the growth parameters as $L\infty$ =87.6 cm, K = 0.33 year^{-1} and t_o = 0.115. They estimated the total mortality coefficient as 1.38 and 2.17 year^{-1} and the fishing mortality as 0.99 and 1.78

year^{-1} for the samples collected during 1996 and 1997 respectively. They applied the method of probability of capture and estimated the length at first capture for *D. labrax* as 22.2 cm.

Abd-Alla (2004) determined the age of *D. labrax* as four and five years during 2000 and 2001 respectively and found that the scales of sea bass in Bardawil lagoon are first formed at 2.0223 and 2.7487 mm length during 2000 and 2001 respectively. He also estimated the constant (b) of length-weight relationship as 2.7977 and 2.7316 during the fishing seasons of 2000 and 2001 respectively. He estimated the back-calculated lengths during 2000 as 22.5, 30.5, 36.4 and 41.8 cm for ages 1 to 4 respectively and during 2001 as 22.3, 31.1, 37.2, 42.9 and 47.5 cm for age groups 1 to 5 respectively. He gave Z values of 1.71 and 1.29 year^{-1} and F values of 1.28 and 0.83 year^{-1} for the samples collected during 2000 and 2001 respectively. The exploitation rates as estimated by Abd-Alla (2004) were 0.748 and 0.644 for years 2000 and 2001 respectively. He attributed the decline in sea bass catch to four factors; increasing the number of licensed fishing boats, replacing the slow wooden boats by faster boats powered by larger motors, destructive new fishing methods and increasing the investments in buying boats and equipment. So, he suggested to limit the effort by controlling the fishing licensed boats and controlling the fishing gears to regulate the gear efficiency to catch larger fishes and make a closed season through two periods, one during August and September and the other during November.

On the other hand, Khalifa (2005b) mentioned that the total length of *D. labrax* during 2004 varied from 22.8 to 63.6 cm, while their weights ranged between 123.3 and 2792 g and the length - weight relationship equation was $W= 0.0078\ L^{3.0551}$, while the length-otolith relationship was $L= -5.173 + 6.8535\ S$, where W is the total weight, L is the total length and S is the otolith radius.

Table 9.18. **Back-calculated lengths of *Dicentrarchus labrax* in Egyptian waters.**

Locality	Sex	Mean length at the end of each year of life							Authors
		1	2	3	4	5	6	7	
Mediterranean	M+F	13.2	18.5	22.0	25.6	29.4	33.3	36.8	Rafail (1971)
Bardawil	M	22.67	27.61						Bebars *et al.* (1986)
	F	23.65	41.28	54.31	63.62	70.15	74.0		
Bardawil	M+F	16.1	30.8	42.5	51.7	59.1	64.9	69.6	Hegazy & Sabry (2001)
Bardawil 2000	M+F	22.5	30.5	36.4	41.8				Abd-Alla (2004)
2001		22.3	31.1	37.2	42.9	47.5			
Port Said 2001	M+F	22.6	31.5	37.9	43.3				Haggag (2005)
2002		23.1	30.9	36.7	41.9				
Bardawil	M+F	22.49	33.38	43.45	49.5				Khalifa (2005)

Khalifa (2005b) found that the maximum life span of *D. labrax* in the Bardawil Lagoon was about four years with the age group 1^+ dominating the catch, where they represented about 85% of the collected sample. He estimated the back-calculated lengths at the end of different years of life as 22.493, 33.381, 43.448 and 49.5 cm for 1^{st}, 2^{nd}, 3^{rd} and 4^{th} years of life respectively. He estimated the constants of the von Bertalanffy's growth model as L_∞ = 72.5 cm TL, K = 0.260 $year^{-1}$, t_0 = -0.396 yr and W_∞ = 3759.738 g, while the growth performance index (Ø) was 3.135.

Table 9.19. **The estimated growth parameters of *Dicentrarchus labrax* in Egyptian waters.**

Locallity	Sex	L∞	K	t_0	Authors
Bardawil	F	86.66	0.33	---	Bebars *et al.* (1986)
Alexandria	M F	87.80 78.00	0.061 0.075	---	Wasef & El-Emary (1989)
Bardawil	M+F	87.6	0.23	0.115	Hegazy & Sebry (2001)
Bardawil 2000 2001	M+F	64.83 65.5	0.2041 0.2183	-1.0887 -0.8448	Abd-Alla (2004)
Port Said 2001 2002	M+F	62.95 61.63	0.240 0.224	-0.842 -1.059	Haggag (2005)
Bardawil	M+F	72.5	0.26	-0.396	Khalifa (2005)

Based on the estimation of total mortality coefficient (1.651 $year^{-1}$) and calculation of fishing mortality coefficient (1.385 $year^{-1}$), Khalifa (2005) estimated the exploitation rate "E" as 0.838. The values of both fishing mortality and exploitation rates were relatively high indicating a high level of exploitation. He estimated the length at first capture as 19.45 cm.

Based on relative yield per recruit (Y/R)' and biomass per recruit (B/R)' analysis, Khalifa (2005b) concluded that *D. labrax* stock in Bardawil Lagoon is still heavily exploited. Predominance of small fish, especially in the catch of trammel nets, indicating "growth overfishing". Therefore, he recommended the reduction of the present level of exploitation rate by about 40% to maintain a sufficient spawning biomass for recruitment and to prevent reaching the status of "recruitment overfishing". Control measures should include effective penalties for illegal fishing. Minimum legal size for sea bass catch should be set at length of 25 cm or more. Finally, a continuous monitoring research program is recommended to reflect the instantaneous changes in the lagoon ecosystem and its fisheries.

Reproductive biology

Reproduction of sea bass takes place in the Mediterranean Sea. All the adult fish leave the Lagoon in late October and November and return to the lagoon after spawning during the second half of February i.e. they are winter spawners. Hegazy & Sabry (2001) found that, females of *D. labrax* attained their first sexual maturity at 25.8 cm in Bardawil lagoon. However, Abd-Alla (2004) determined the length at first sexual maturity as 23.4 and 23.0 cm for males in 2000 and 2001 respectively, and 30.4 and 31.0 cm for females during the same years respectively.

Food and Feeding habits

The sea bass *D. labrax* is a predator, consuming small fish and a large variety of invertebrates especially shrimps. Its feeding behavior is related to its size. Juveniles feed mainly on small crustaceans (Amphipoda, Mysidacea, Isopoda) and small fish like *Atherina* and *Gobius*. For fish larger than 20 cm, shrimps and crabs begin to be common preys.

9.4.5 Shrimps

Shrimps are considered recently as one of the most valuable fishery resources in Bardawil Lagoon. They were recorded in Bardawil's production for the first time during the fishing season of 1994, where they were represented by about 1.83 tons, which constituted about 0.12% of the total production of the lagoon. Then they markedly increased to 273.9 tons during 1995 then decreased to about 75 tons in 1996, after which the shrimp catch fluctuated between 270.9 tons during 1998 and 813.4 tons during 2002, contributing about 26.4% of the total lagoon production. The shrimp catch declined to about 329 tons in 2004 then increased to 775 tons in 2005, forming about 21.9% of the total lagoon production (Fig. 9.20). Shrimps constituted about 18.6% of the total lagoon production (1994-2005) which contributed about 35% of the gross revenue from the lagoon.

The monthly catch of shrimp during the period from 1994 to 2005 show that the most productive months were those at the beginning of each fishing season, thus more than 77% of the annual shrimp catch landed during the first three months of the season (April, May and June), and then the landings progressively decrease towards the end of the season in December.

Six shrimp species have been recorded in Bardawil lagoon namely: *Metapenaeus stebbingi* Nobili 1904, *Penaeus japonicus* Bate 1888, *P. semisulcatus* De Haan 1850, *P. kerathurus* Forskal 1775, *Metapenaeus monoceros* Fabricius 1798, and *Trachypenaeus curvirostris* Stimpson, 1860. The green tiger prawn *P. semisulcatus* is considered the most economic penaeid species in the lagoon due to its relatively large size (19.5 cm total length) and high

prices, while *M. stebbingi* is the most abundant shrimp species, where it constitutes about 71% of the shrimp catch.

Ameran (2004) studied the biological and dynamic parameters for *M. stebbingi* collected from Bardawil lagoon during the fishing seasons of 1999 and 2000. He found that the total length of this species varied from 4.35 to 7.8 cm during 1999 and from 4.23 to 7.2 cm during 2000 for males and varied from 3.8 to 10.1 cm (1999) and from 3.8 to 9.18 cm (2000) for females. He estimated the following length-weight relationship equations:

Males $W = 0.0273\ TL^{2.3422}$ (1999)

$W = 0.0297\ TL^{2.2843}$ (2000)

Females $W = 0.024\ TL^{2.4743}$ (1999)

$W = 0.0208\ TL^{2.5294}$ (2000)

The von Bertallanfy growth parameters (Table 9.20) were estimated for males as $L_\infty = 8.11$ cm TL, $K = 2.748$ year^{-1}, $t_o = -0.0438$ yr (1999) and $L_\infty = 7.6$ cm TL, $K = 2.578$ year^{-1}, $t_o = -0.0636$ yr (2000) and for females as $L_\infty = 10.42$ cm TL, $K = 2.117$ year^{-1}, $t_o = -0.012$ yr (1999) and $L_\infty = 9.7$ cm TL, $K = 2.079$ year^{-1}, $t_o = -0.026$ yr (2000).

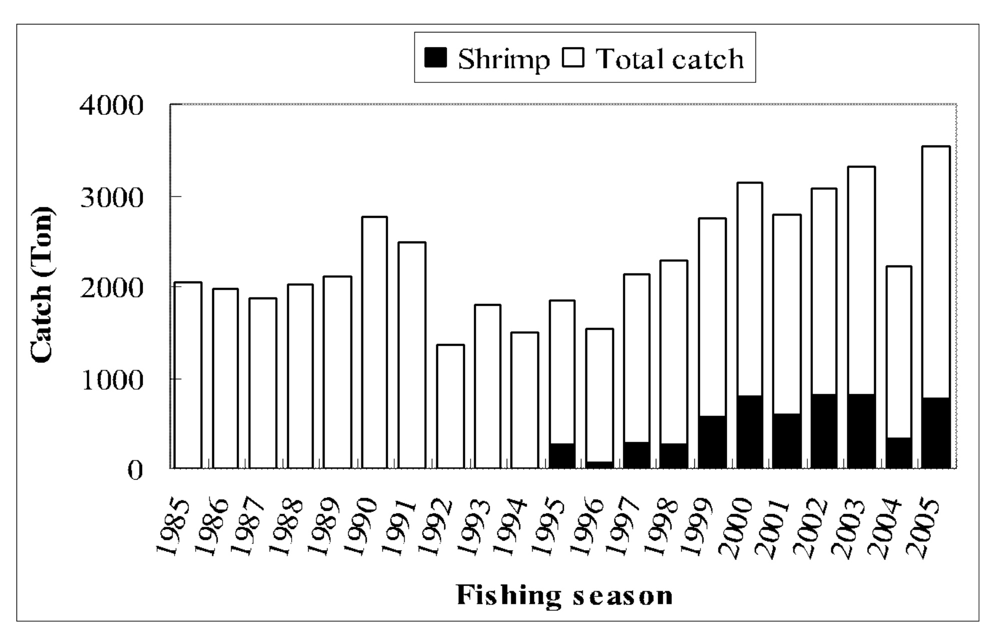


Fig. 9.20. **Shrimp and total catch of Bardawil Lagoon during the period from 1985 to 2005**

Table 9.20. **Growth parameters of *Metapenaeus stebbingi* from Bardawil lagoon (Ameran 2004).**

Males

Fishing Season	1999		2000	
CONSTANTS	FORD- WALLFORD	GULLAND	FORD- WALLFORD	GULLAND
L_∞	8.11	8.11	7.60	7.60
K	2.7480	2.4016	2.5778	2.4879
t_0	-0.0438	-0.0438	-0.0636	-0.0636
W_∞	3.67	3.67	3.05	3.05

Females

Fishing Season	1999		2000	
CONSTANTS	FORD- WALLFORD	GULLAND	FORD- WALLFORD	GULLAND
L_∞	10.42	10.42	9.70	9.70
K	2.1166	2.0648	2.0793	2.0310
t_0	0.0117	0.0117	-0.0257	-0.0257
W_∞	7.20	7.20	6.51	6.51

The total mortality coefficient was estimated as Z = 6.48 and 8.844 per year for males during 1999 and 2000 respectively, while Z = 5.723 and 5.969 per year for females during 1999 and 2000 respectively (Ameran 2004).

On the other hand, Yassien (2004) studied the fishery and population structure of *P. semisulcatus* in Bardawil Lagoon during 1999. The relationships between the prawn weight and each of the total length, carapace length and body length as well as the relationship between the total length and carapace length are shown in Table 9.21. Females predominated in the total catch (1 males: 1.48 females) for most months, except in autumn months (October, November and December).

Table 9.21. **Summary of the different morphometric relationships for *Penaeus semisulcatus* from Bardawil Lagoon (Yassien 2004).**

X	Y	a	b	r^2	95% confidence interval	
					Lower	Upper
Males						
Total length (cm)	Total weight (g)	0.0125	2.8111	0.9337	2.7194	2.9068
Carapace length	Total weight	0.3321	2.5423	0.8705	2.3841	2.6193
Body length	Total weight	0.0175	2.8524	0.9214	2.6991	3.0056
Total length	Carapace length	0.1115	0.3426	0.9452	0.3177	0.3719
Females						
Total length	Total weight	0.0098	2.9291	0.9632	2.8293	2.9606
Carapace length	Total weight	0.1981	2.9797	0.9687	2.8341	3.0535
Body length	Total weight	0.0174	2.8820	0.9546	2.7938	2.9658
Total length	Carapace length	0.1009	0.3447	0.9825	0.3258	0.3969

Age and growth studies of *P. semisulcatus* show that the life span of males is 18 months, while that of females is 24 months. The species is characterized by fast growth, attains 16.5 cm and 18.9 cm in total length (5.8 cm and 6.6 cm carapace length) after 18 and 24 months for males and females, respectively. The assigned seasonal modal lengths indicate that the rate of growth of males is about 7.0 mm per month, while that of females is about 7.7 mm per month (Yassien 2004).

A summary of the estimated von Bertalanffy growth parameters that describe growth in length (L_∞, K and t_0) and the derived growth performance index are presented in Table (9.22). The estimated growth performance index was slightly higher for females with similar sizes.

The von Bertalanffy growth equations for both males and females were described as:

$$L_t = 19.721\,(1 - e^{-1.104\,(t + 0.230)}) \quad \text{for males}$$

$$L_t = 22.149(1 - e^{-1.004\,(t - 0.018)}) \quad \text{for females}$$

Table 9.22. **Growth parameters of *P. semisulcatus* in Bardawil Lagoon (Yassien 2004).**

	Estimates	Standard error	Coefficient of variation
Males			
L_∞	19.721	1.894	0.093
K	1.104	0.067	0.241
t_0	- 0.230	0.238	- 1.036
Ø	2.056	0.557	0.271
Females			
L_∞	22.149	0.578	0.026
K	1.004	0.018	0.070
t_0	0.018	0.079	1.381
Ø	2.090	0.543	0.260

The total mortality rate of *P. semisulcatus* was found to be Z = 7.391 y^{-1}, while that of females was Z = 6.253 y^{-1}. The natural mortality (M) was calculated as M = 1.956 y^{-1} for males and 1.795 y^{-1} for females. The corresponding estimates of the fishing mortality rates were F = 5.435 y^{-1} and F = 4.458 y^{-1} for both sexes respectively.

The exploitation ratio (E=F/Z) was calculated as E = 0.735 for males and for females E = 0.713. According to Gulland (1971) the optimum exploitation ratio is E_{opt} = 0.5 and this implies that the stock of *P. semisulcatus* in Bardawil Lagoon is heavily exploited and the fishing pressure exerted in the lagoon is very high.

These figures indicate that the present values of the exploitation ratio for males (E = 0.735) and E = 0.713 for females are higher than that associated

with the maximum relative yield per recruit (E_{max} = 0.607 and 0.565 for males and females respectively). This means that the fishing pressure exerted in the Bardawil Lagoon must be reduced by about 20-25% of its current value to sustain the maximum yield. Therefore, utmost caution must be taken in the future fisheries management and a full assessment of the multispecies resource base should be done.

9.4.6 The Blue Crab

The blue swimming crab *Portunus pelagicus* (Linnaeus) represents a valuable component of small-scale coastal fisheries in tropical and temperate latitudes including Egypt. Its distribution extends from the southern Mediterranean Sea, Red Sea, and the east coast of Africa and across the Indian Ocean to Japan and the western Pacific Ocean.

Crabs and shrimps are considered recently the most valuable fishery resources in Bardawil Lagoon The catch composition in the lagoon were greatly changed specially during the fishing' seasons from 1994 to 2005 (Fig. 9.21) . Crustaceans have been recorded in the catch in significant quantities during late 1990's. Throughout the period from 1987 to 1995, the catch of the crab progressively increased from 19.7 to 491.7 tons. A continuous increase occurred to reach 1321.8 tons in 2005, which represents 37.4% of the total yield production of Bardawil Lagoon and about 40% of the total crab yield from all Mediterranean fisheries centers of Egypt (GAFRD 2005). Predomination of crustaceans (crabs and shrimps mainly) could be attributed to either flourishing of their stocks in the lagoon or to a change in the exploitation rate for Bardawil fisheries. Flourishing of their stock may be because of dredging of the inlets, which provided suitable environmental conditions, or due to a decline in their common predator, which influence the suitability of the ecological niche.

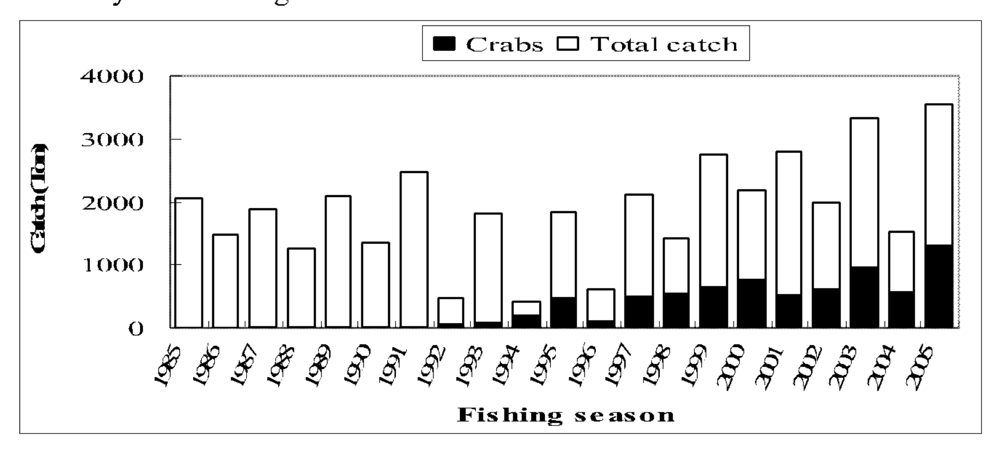


Fig.9.21. **Crab and total catch of Bardawil Lagoon during the period from 1985 to 2005**

Abdel Razek *et al.* (2006) studied the fisheries of the swimming crab *Portunus pelagicus* in details during 2004/05 season. They found that the

maximum production of crabs was during May and June and sometimes extends to October. Fig. (9.22) illustrates the mode of size frequency distribution of the crab *P. pelagicus* population in Bardawil Lagoon during the three different years 1999 and 2000 (Ameran 2004) and 2004-2005 (Abdel Razek *et al.* 2006).

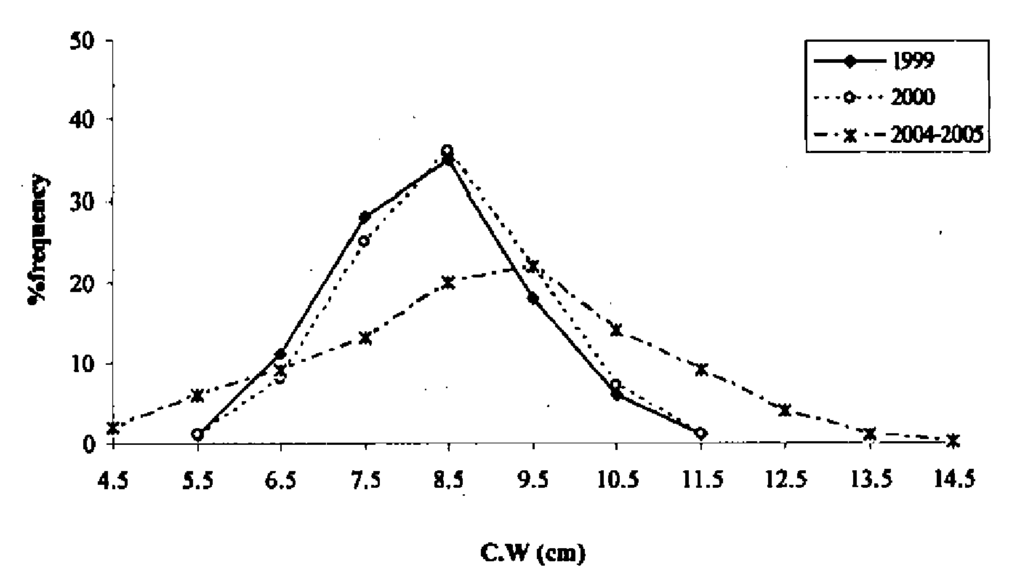


Fig. 9.22. **Size population structure of *P. pelagicus* in Bardawil Lagoon during 1999, 2000 and 2004/05 (Abdel Razek *et al.* 2006).**

There were two modes of abundance, the first was at 8.0-9.5 cm carapace width during 1999 and the second was in the year 2000 with a size range from 5.0 to 12.0 cm, while it was shifted to be from 9.0 to 10.0 cm during 2004-2005 with a wider size range from 4.0 to 15.0 cm. The size range for both sexes was ranging from 4.0 to 15.0 in carapace width. The maximum abundance of females was at small sizes from 4.0 to 5.0 cm as well as at larger sizes from 13.0 to 15.0 cm. Males were predominating from 5.0 to 12.0 cm carapace width. Abd Elrazek *et al.* (2006) observed that the abundance of larger sizes of females and males was during September; October, November and December. Individuals of size range from 11.0 to 15.0 cm carapace width were represented by small numbers. Meanwhile, the smaller size of both sexes appeared in the population from January to May with a size range from 4.0 to 8.0 cm carapace width.

The carapace length (C.L) of *P. pelagicus* varies from 1.9 cm to 7.0 cm and the carapace width (C.W) from 4.3 cm to 14.2 cm (Table 9.23).

The relationships between the two variables for both sexes are represented by the following equations:

Females $C.W = 2.1313\ CL - 0.3202$ $r^2 = 0.9602$

Males $C.W = 1.9689\ CL + 0.1701$ $r^2 = 0.9345$

There is a significant difference between sexes in the slopes of carapace width -carapace length relationships ($P > 0.05$).

The relationship between the carapace width (C. W) and the body weight (W) (at weight range from 5.5 g to 183.3 g) for both sexes (Table 9.23) are represented by the following equations:

Females T. wt = 0.0743 C. W 2.9517 r2= 0.9736

Males T. wt = 0.0449 C. W 3.2062 r2= 0.9334

Table 9.23. **Summary of the different morphometric relationships for *P. pelagicus* in Bardawil Lagoon (Abdel Razek *et al.* 2006).**

.3	Female			Male		
	a	b	r^2	a	b	r^2
Length-Length CL $_{VS}$ CW	-0.3202	2.1313	0.9602	0.1701	1.9689	0.9345
Length-Weight CL $_{VS}$ TW	0.4678	3.1458	0.9537	0.4054	3.2269	0.9031
CW $_{VS}$ TW	0.0743	2.9517	0.9736	0.0449	3.2062	0.9334

CL = Carapace Length (cm) r = Coefficent of determination
C.W = Carapace width (cm) a = Intercept
T.W = Total weight (g) b = Regression coefficient

The relationship between the carapace (C. L) and body weight (W) for both sexes is given in the following equations:

Females T. wt = 0.4678 CL 3.1458 r2 = 0.9537

Males T. wt = 0.4054 CL 3.2269 r2 = 0.9031

Reproductive biology

Abdel Razek *et al.* (2006) indicated that the abundance of stage III (maturing) and stage IV (late mature) was found during the period from April up to November, while individuals with spent gonads were observed from February to May. On the other hand, the immature (I) individuals were observed all the year round, with maximum abundance during December, January and March. Berried individuals were recorded during the period from June to October by small numbers.

Table 9.24 described the distribution of the female's maturity stages according to their sizes in Bardawil Lagoon during 2004/05 season. The stages, maturing (III), late mature (IV), spent (V) and berried (VI) were observed in crabs of carapace width starting from 8.5 cm up to 14.5 cm and the percentage of abundance increased with increase of the size. Immature individuals are related to the sizes from 3.5 cm to 11.5 cm, with a maximum occurrence from 3.5 to 6.5 cm carapace width. The present distribution indicates that immature individuals of *P. pelagicus* entered Bardawil Lagoon in winter from December, January and March with smaller crab sizes, while ripening and mature gonads always appear from spring to autumn with larger- size individuals.

Monthly distribution of Gonadosmatic index (G.S.I) is shown in Fig. 9.23. Increase in the females G.S.I, starts from June to September with a peak in August for crab size- range of 9.5 to 13.5 cm carapace width with a peak at 12.5 cm.

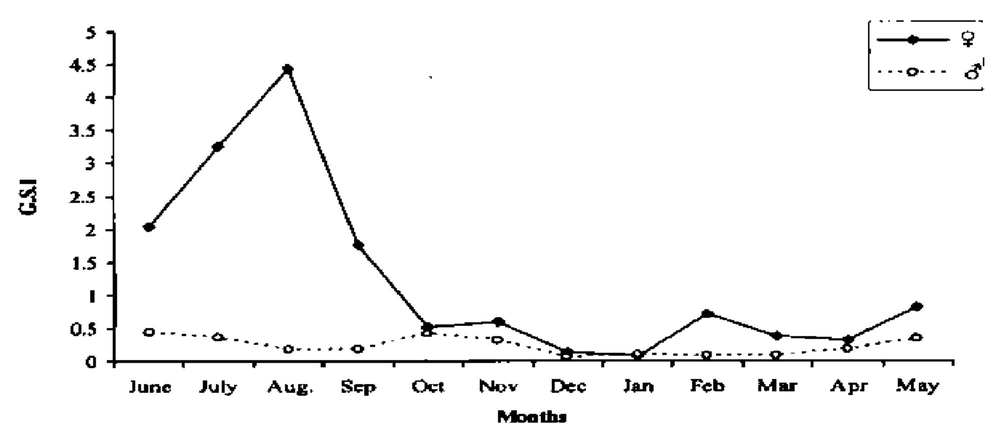


Fig.9.23. **Monthly distribution of GSI of *P. pelagicus* in Bardawil Lagoon during (2004 /2005) (Abdel Razek *et al.* 2006)**

Table 9.24. **Size distribution of different maturity stages of *P. pelagicus* female in Bardawil lagoon during 2004-2005 (Abdel Razek *et al.* 2006).**

Maturity stages Average C.W	Immature	Early mature	Mature	Late mature	Spent	Berried
	I	II	III	IV	V	
3.5	100	-	-	-	-	-
4.5	100	-	-	-	-	-
5.5	100	-	-	-	-	-
6.5	100	-	-	-	-	-
7.5	95	5	-	-	-	-
8.5	91	5	1	1	1	-
9.5	68	10	7	3	8	4
10.5	34	11	13	3	28	10
11.5	15	12	26	9	29	-
12.5	-	-	20	25	55	9
13.5	-	-	17	33	50	-
14.5	-	-	-	-	100	-

This observation proves that maturation and spawning activity of *P. pelagicus* take place in the period from June to September in Bardawil Lagoon.

Abdel Razek *et al.* (2006) indicated that the presence of very small numbers of ovigorous *P. pelagicus* females during 2004/05 in Bardawil Lagoon

needs continuous study about whether *P. pelagicus* spawns inside or outside the lagoon.

9.5 MANAGEMENT

The main objective of fisheries management is to maintain or restore exploited populations at levels that can produce the maximum sustainable yield "MSY" as qualified by relevant environmental and economic factors. In this respect, a primary step is to protect stocks from over-fishing, and a second step is to optimize the utilization levels, in order to maintain the stocks large enough that when harvested, it can produce the MSY.

The management strategies and techniques are classified into two, not entirely distinct, categories which are; the regulation of catch-age composition and the regulation of the fishing effort. Two main groups of fish stock assessment models are used to achieve these objectives, namely: surplus production models and analytical models.

The surplus production models of Schaefer (1954), Fox (1970) and Walters & Hilborn (1976) and the relative yield per recruit and relative biomass per recruit of Beverton and Holt (1966) as an analytical model were used to evaluate the status of the exploited fish and crustacean species in Bardawil Lagoon.

Anonymous (1992), based on Schaefer and Fox models, assessed the MSY in Bardawil lagoon as 2140.87 tons by the use of 678 standardized Dabba units and split to 566 Dabba units and 113 Veranda fishing units.

Applying the surplus production model of Fox (1970) on the catch and effort of *M. cephalus* in the period from 1980 to 1996 showed that the maximum sustainable yield (MSY) of the grey mullet in Bardawil Lagoon was 650.3 tons and can be achieved by 87.4 veranda boats (Breikaa 1997). These results indicate that the maximum sustainable yield (MSY) of the grey mullet can be realized by reducing the fishing veranda fleet by about 42.5% of its current value. Breikaa (1997) also, estimated the maximum sustainable yield in Bardawil Lagoon as 2252 tons corresponding to 653 standardized Dabba units which can split into 87 veranda fishing vessels and 501 Dabba fishing vessels.

The surplus production model derived by Schaefer (1954) was applied for a series of catch and effort data from 1980 to 2001. The used efforts were measured in number of standardized fishing boats, while the catch data were quoted from the records of the General Authority of Fish Resources Development. The estimated maximum sustainable yield MSY = 2189 tons corresponding to an optimum effort of f_{MSY} = 1019 standardized boats. These results indicate that the fishery of Bardawil Lagoon is heavily exploited, since the effort associated with MSY is higher than the average exerted effort by about 20%.

For the proper management of the fishery in Bardawil Lagoon, the estimated total standardized Dabba units (1019) can split into 876 Dabba fishing vessels and 143 Veranda fishing vessels, thus reducing the fishing fleet by about 175 fishing vessels will lead to an annual catch of 2189 tons on the long term.

The recommendations of Anonymous (1992) and Breikaa (1997) have not taken in to consideration. Moreover, the number of operating fishing vessels have increased by 50 vessels in 2002 and progressively increased until 2005. This would lead to a serious depression in the valuable lagoon production.

Recently, Mehanna (2006b) collected the fishery statistics of Lake Bardawil allover 26 years (1980-2005) and applied a surplus production model (Walters & Hilborn 1976) to assess the current status of the lake and to define the main challenges facing the development of the lake.

To evaluate the effect of fishing effort on the stocks exploited by the different fishing gears in Lake Bardawil, all fishing methods operated in the lake are standardized according to Dabba fishing boats. The standardized fishing effort and Catch per unit of fishing effort during the fishing seasons from 1980 to 2005 are used as inputs for the surplus production model of Walters & Hilborn (1976) to estimate MSY and f_{MSY} as limiting or threshold reference points. Also, 2/3 MSY and 2/3 f_{MSY} as precautionary target reference points were calculated. The obtained results are represented in Fig. 9.24.

The results revealed that, a maximum sustainable yield of 2320 tons could be obtained at fishing effort f_{MSY} of 1458.6 standard fishing units. This means that the present level of fishing effort (1760 standard units) is higher than needed to produce MSY by about 17.12%. The use of 2/3 f_{MSY} criteria revealed that the present level of fishing effort must be reduced by about 44.7%. This reduction in fishing effort will be associated with an increase in fish abundance index by about 75%.

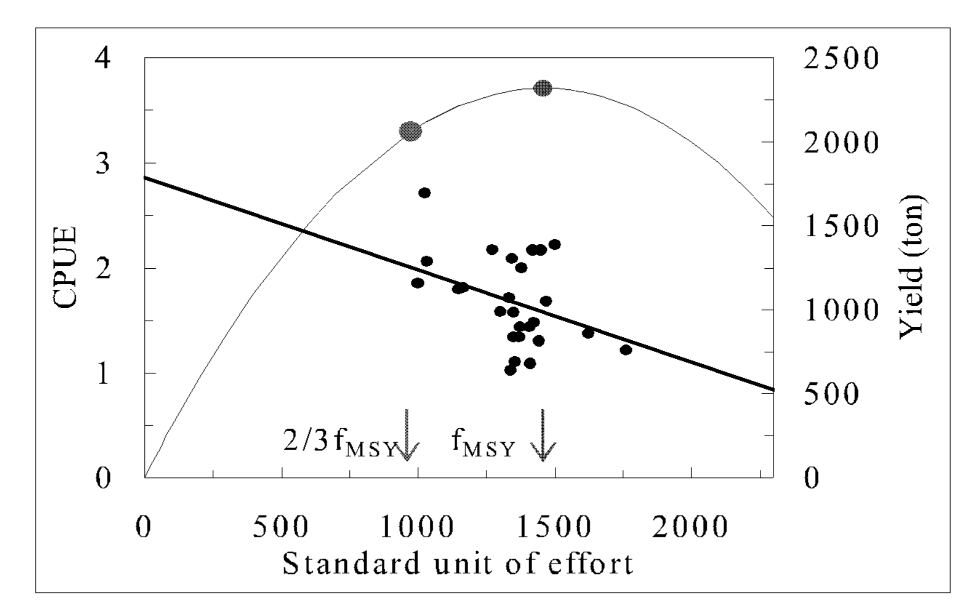
Both of analytical models and surplus production models revealed that all fish and crustacean stocks at Bardawil lagoon are suffering from over-fishing and the present fishing effort should be decreased to maintain these valuable resources.

Mehanna (2006b) mentioned that over-fishing is not the only challenge facing the development and management of Lake Bardawil fisheries, but a number of problems were identified such as illegal mesh sizes, destructive fishing methods, high salinity, and great fluctuation in temperature, tourism and hunting as well as the biological enemies such as water-birds. Although, Bardawil is a Ramsar Site, no protection has been granted at the national or local level. However, the eastern extremity of the site lies within the Zaranik Protected Area. *Phalacrocorax carbo* causes substantial damage to fisheries of Bardawil; where one estimate suggested that 6% of Bardawil's fish production

is lost by this bird species in winter of 1989/90. It appears that the numbers of wintering birds at Lake Bardawil, as well as at other Egyptian wetlands in the northern delta, are growing. To reduce the damage, the fisheries authority has arranged shooting parties over the past few years to try to control these bird populations on a regular basis and attempted to allow fishing throughout the winter, in order to increase disturbance to the birds. These measures apparently did not prove effective in resolving the problem. Meanwhile, they cause increased disturbance and many casualties amongst non-target species, as well as a severe decline in fish productivity of the lake.

Fig. 9.24. **The f_{MSY} as a limited reference point and 2/3 f_{MSY} as a target reference point for Lake Bardawil fishery.**

The North Sinai Agriculture Development Project (NSADP), which aims at claiming for irrigation of 400,000 acres in North Sinai, will completely



change the landscape of Bardawil. The lake will potentially become increasingly brackish as agricultural drainage water reaches it, either through direct discharge or through seepage. Drastic growth in human population will occur, increasing urban encroachment pressures and introducing pollution problems in the area. In addition to Land claim, land is being sold along the lakeshore for tourism development, particularly at the western coast of the lake.

The following elements could be suggested for management of the Lake:

- Regulation of mesh sizes, controlling gear types used, developing suitable fishing gear for shallow lagoons and prohibition of the destructive fishing methods.

- Monitoring salinities at various seasons and localities
- Setting limits for a total allowable catch from the lake.
- Studying the biology, dynamics and reproductive cycle of the commercial fishes of the lake as this is an important step in establishing guidelines for fishery-regulation measures.
- Continuous clearance of inlets for exchange of water masses between the lake and the open sea.
- Revision of fisheries laws and improving the system for collecting and compiling fisheries statistics

Finally, specific research projects are required, such as fishing gear development and multi-species fishing gear management. Such projects should provide information about fishing, tourism and hunting, biological resources such as birds, mammals, zooplankton, aquatic plants, hydraulic and hydrologic data (water levels and flows) and ecosystem components.

9.6 SUMMARY

Lake Bardawil is so far the cleanest marine water body in Egypt, as well as in the entire Mediterranean region. It is an important source of local fishery in north Sinai and the country.

Fish species inhabiting Bardawil Lagoon originate from the Mediterranean Sea and Red Sea via Suez Canal. However, the pronounced fluctuations in the hydrographic and biological conditions prevailing in the Lagoon (strong seasonal and diurnal changes in salinity and temperature) limit the number of species that are capable of thriving there to a few dozens only. The species found are by nature eurytopic, especially in their tolerance to both low and high salinities. Sixty species of fishes were collected from the lagoon during 1970s, but recently during 2000s, 44 species only were listed. The Red Sea origin fishes in Bardawil constitute about 25% of the total recorded species.

The common commercial fishes of the Bardawil Lagoon are the gilthead bream (*Sparus aurata*), grey mullets (Mugilidae), the sea bass (*Dicentrarchus labrax*) and the common sole (*Solea solea*).

The fish catch was about 196 tons during 1920s and increased gradually to reach 371 tons in 1930s, and *Mugil cephalus* and *Liza ramada* were the most important species in catches during this period. During 1960s, the production average reached approximately 2310 tons per year and the catch was composed mainly of the Gilthead sea bream, with an average yield of about 48.49% of the total catch. During 1970s, the catch varied from 900 in 1971 to 2650 tons in 1977, and showed considerable variations in the species composition. These variations reflect the influence of three main factors: 1. changes in the salinities

prevailing in the Lagoon; 2. increase in fishing effort; 3. new fishing regulations introduced in years 1973-1975. A striking decrease in the catch of the gilthead bream (*Sparus aurata*) has been detected in the years 1969-1971, from about 1,000 tons in 1969 to only 180 tons in 1971; one year after the 1970 peak of high salinities. It is assumed that the abnormally high salinities prevented both the adult and the young fish from settling in the Lagoon.

On the other hand, there was another dramatic change in the catch composition of the lagoon during the last two decades. Crustaceans (shrimps and crabs) production has greatly increased in the lagoon, reaching about 60 % of the total catch in 2005, affecting the catch of other economic fish species like sea bream and sea bass. During 1980s, Sparidae (*Sparus aurata*) constituted about 60 % of the total catch of the lake. This catch decreased to about 15 % of the total fish production in early 1990's and to 8.29% during 2005.

This serious change in catch composition during the last 20 years can be attributed to a number of factors including: change in ecological conditions of the lagoon, increased of fish export and the overexploitation since late 1980's up till now. These factors led to decreasing of sea bream and sea bass production. On the other hand, the appearance and domination of crustacean species could be attributed to the dredging of inlets, which provided suitable environmental conditions that led to flourishing of their stocks and to changing in the fishing procedures in Bardawil Lagoon. Prohibition of purse-seine fishing technique in 1993 reestablishment the sea grass beds in the lagoon, which represent a suitable ecological niche for shrimp .The appearance of crustacean species led to introduction a new fishing technique to catch them (kalsa fishing technique or trawl nets). This fishing method was very destructive, and contributed to catch the fish fry of bottom feeders, like soles, sea bream and sea bass, resulting to progressive decline in their stocks.

Moreover, the great change in salinity of the lake gave the chance to several fish species inhabiting Mediterranean coast off Bardawil to find a safe shelter and rich grazing area in the lagoon. For example, several new-recorded species have appeared and established themselves in the lagoon ecosystem, e.g. *Tilapia zillii*, *Siganus rivulatus* and *Hemiramphus far*. Their production increased from year to year, indicating that they find their suitable habitat in the lagoon.

Two main fishing techniques are licensed to operate in Bardawil Lagoon; namely Dabba and Bouss methods. Actually, there are also nine illegal fishing gears that operate in the lagoon in different months, according to the appearance and abundance of different species. The Dahbana gear appeared in 1988 for catching mullets, but it was a destructive gear for the sea bream juveniles. In 1995, the trawling nets were used for catching shrimps; this gear is very destructive for the juveniles of sea bream, groupers and rabbit fishes.

The catch per unit of fishing effort (CPUE) provides an indicator of the relative abundance of the different fish stocks and consequently the status of the fishery. The total CPUE in Lake Bardawil varied between a minimum of 0.9 ton/boat during 1992 and a maximum of 2.7 ton/boat during 1982. After the fishing season of 2000, a noticeable decrease in the CPUE was recorded, reflecting the fish abundance in the lagoon during the last six years.

Both of analytical models and surplus production models revealed that all fish and crustacean stocks at Bardawil lagoon are suffering from over-fishing, and the present fishing effort should be decreased to maintain these valuable resources.

Over-fishing is not the only challenge facing the development and management of Lake Bardawil fisheries, but a number of problems were identified, such as illegal mesh sizes, destructive fishing methods, high salinity, and great fluctuation in temperature, tourism and hunting as well as the biological enemies such as water birds. *Phalacrocorax carbo* causes substantial damage to fisheries of Bardawil; where one estimate suggested that 6% of Bardawil's fish production is lost by this species.

The following elements could be suggested for management of the Lake:

1- Regulation of mesh sizes, controlling gear types used, developing suitable fishing gear for shallow lagoons and prohibition of the destructive fishing methods.
2- Monitoring salinities at various seasons and localities
3- Setting limits for a total allowable catch from the lake.
4- Studying the biology, dynamics and reproductive cycle of the commercial fishes of the lake as this is an important step in establishing guidelines for fishery-regulation measures.
5- Continuous clearance of inlets for exchange of water masses between the lake and the open sea.
6- Revision of fisheries laws and improving the system for collecting and compiling fisheries statistics

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9.8 PLATES (9.1 – 9.18)

(Bishai & Khalil 1997; Photos of S. F. Mehanna; Website: www.fishbase.org 2000)

Plate 9.1

Anguilla anguilla
Atherina boyeri

Plate 9.2

Tilapia zillii
Hemiramphus far

Plate 9.3

Dicentrarchus labrax
Dicentrarchus punctatus

Plate 9.4

Mugil cephalu

Liza ramada
Liza aurata

Plate 9.5

Liza carinata

Mullus barbatus

Mullus surmuletus

Plate 9.6

Caranx rhonchus
Pomadasys stridens

Argyrosomus regius

Plate 9.7

Umbrina cirrosa
Scorpaena porcus

Plate 9.8

Epinephelus aeneus

Siganus rivulatus

Plate 9.9

Siganus luridus
Solea solea

Plate 9.10

Solea aegyptiaca
Sparus aurata

Plate 9.11

Lithognathus mormyrus
Dentex dentex

Plate 9.12

Boops boops
Crenidens crenidens
Diplodus annularis

Plate 9.13

Terapon puta
Pelates quadrilineatus

Plate 9.14

Hippocampus fuscus

Penaeus japonicus

Plate 9.15

Penaeus kerathurus

Penaeus semisulcatus

Plate 9.16

Metapenaeus stebbingi
Trachypenaeus curvirostris

Erugosquilla massavensis

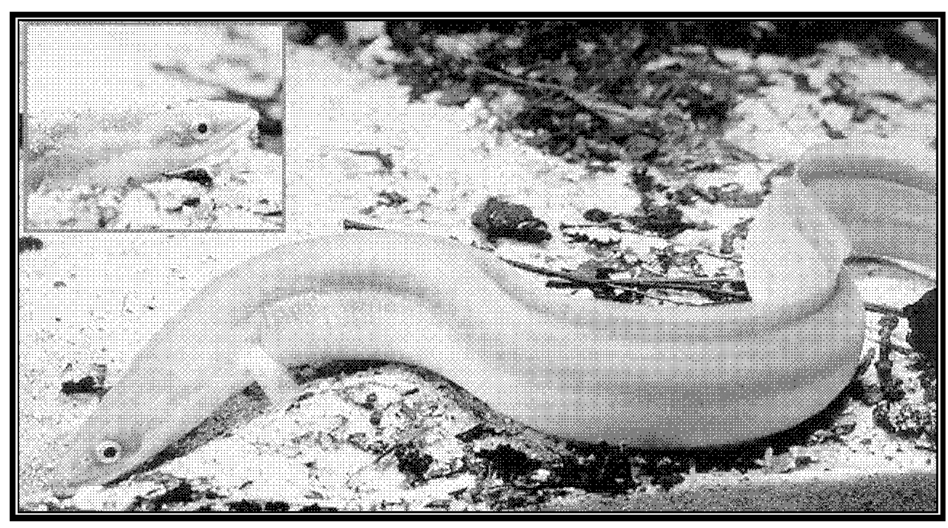
Plate 9.17

Portunus pelagicus

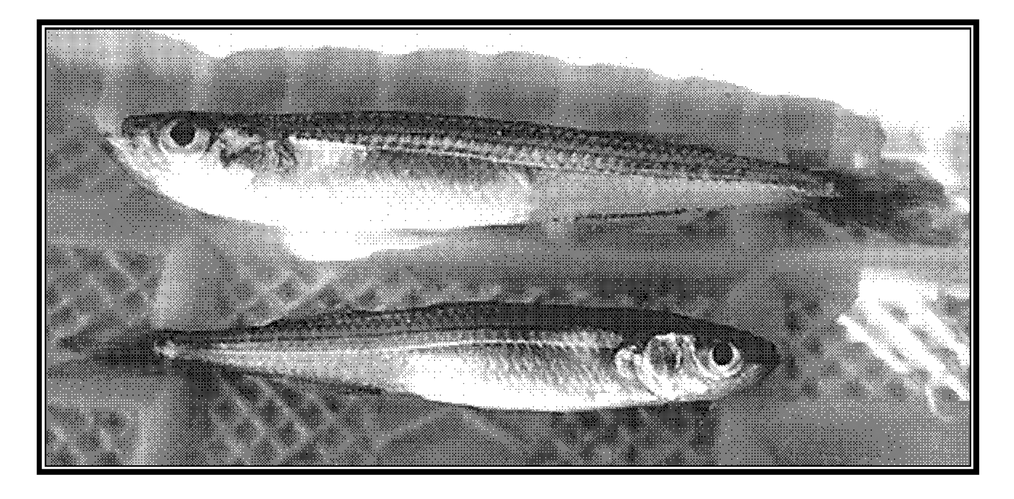
Plate 9.18

Callinectes sapidus

Plate 9.1

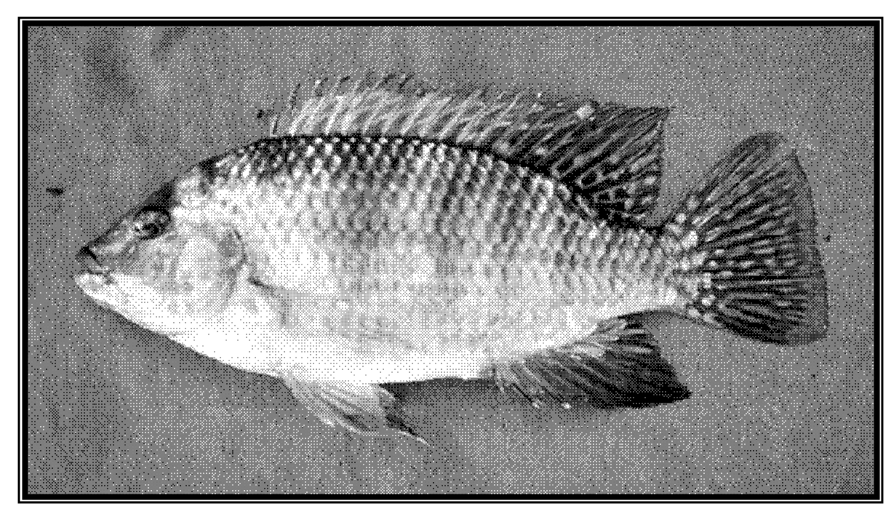


Anguilla anguilla ثعبان السمك

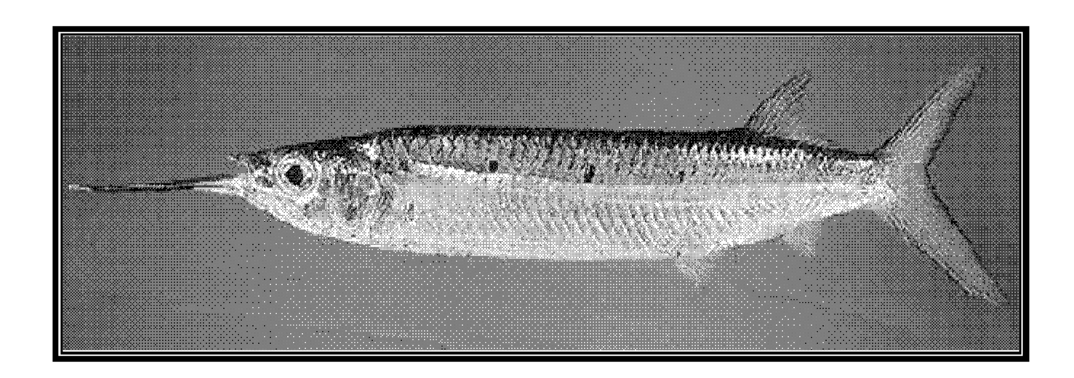


Atherina boyeri بساريا

Plate 9.2

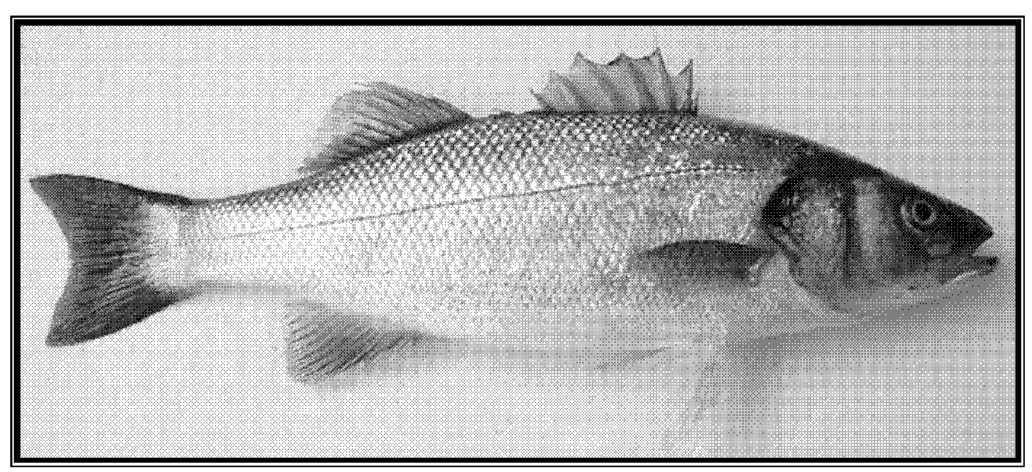


Tilapia zillii بلطي أخضر

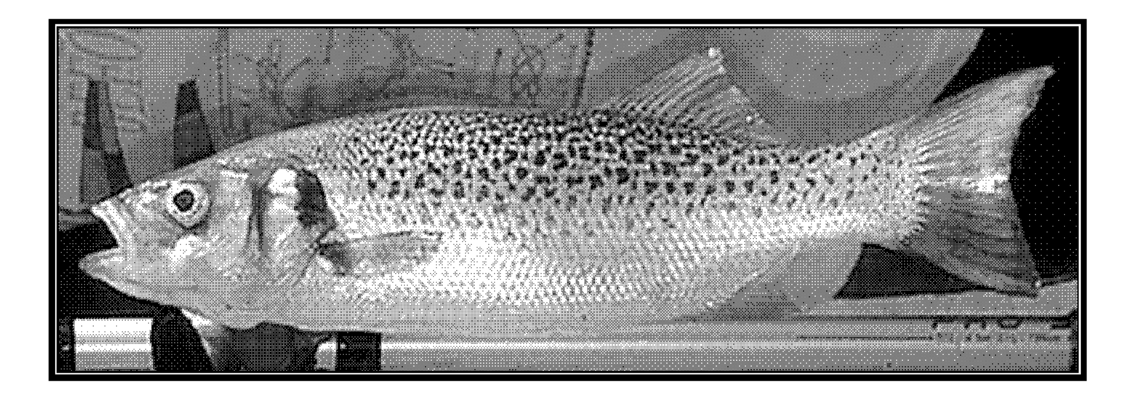


Hemiramphus far أبو منقار

Plate 9.3

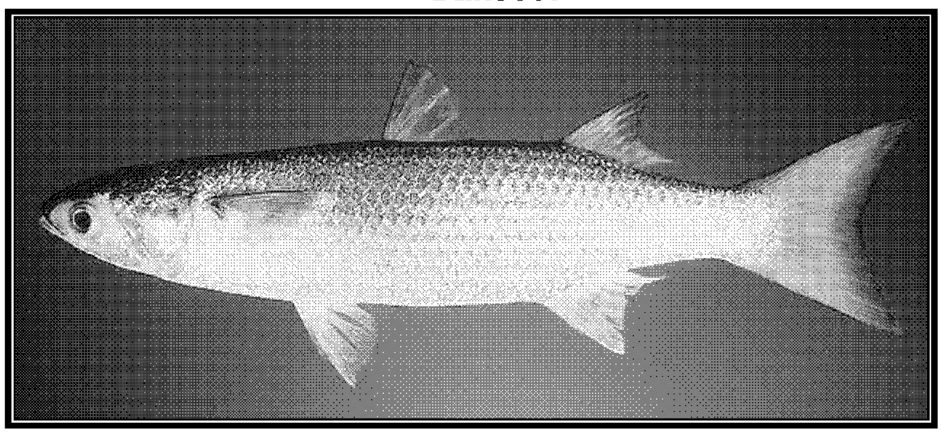


Dicentrarchus labrax قاروص

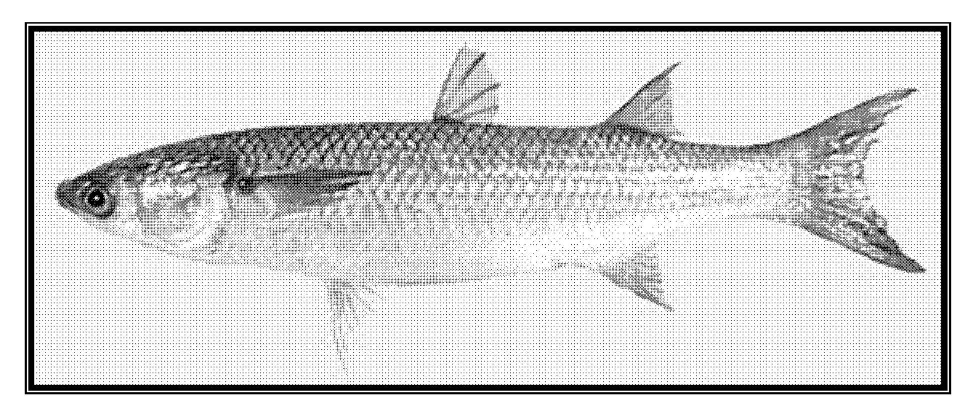


Dicentrarchus punctatus نقط

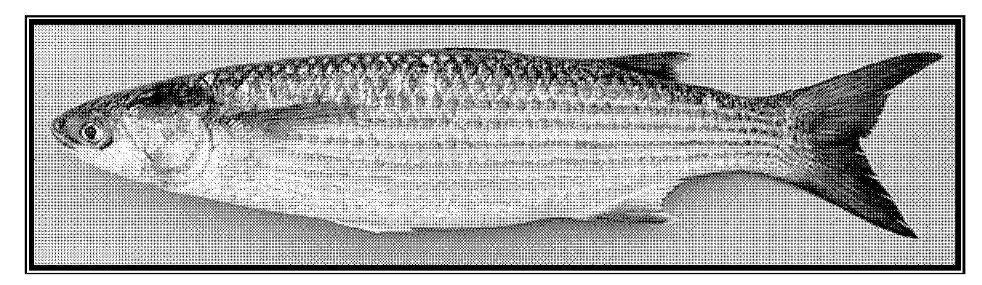
Plate 9.4



Mugil cephalus بورى

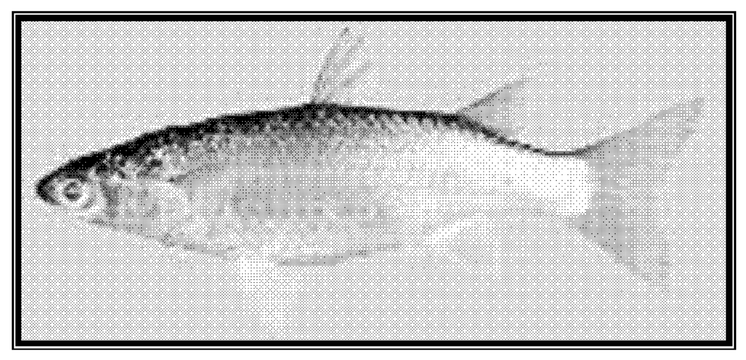


Liza ramada طوبارة

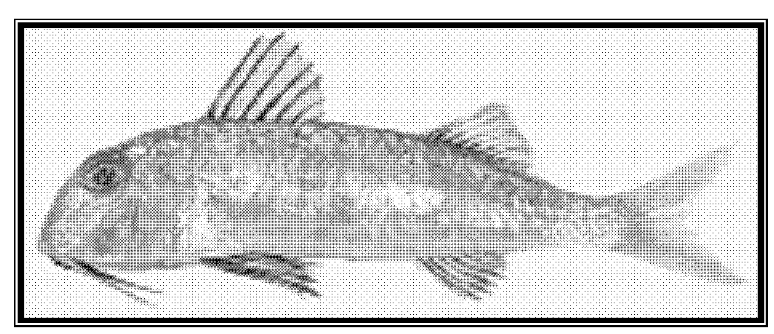


Liza aurata دهبانة

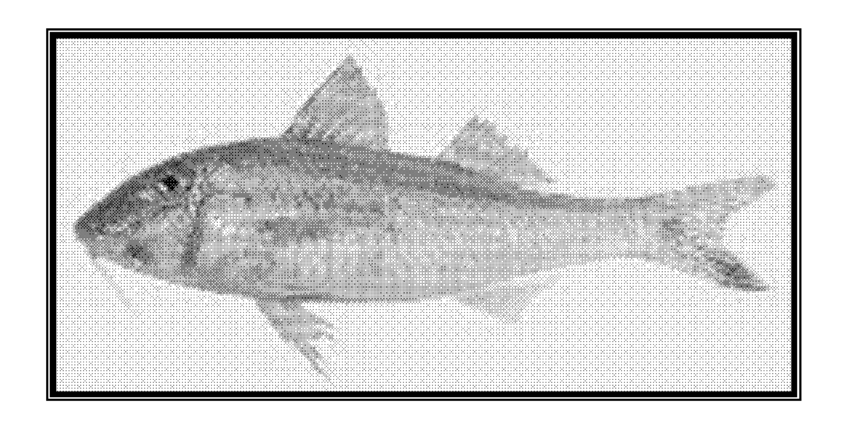
Plate 9.5



Liza carinata سهلية

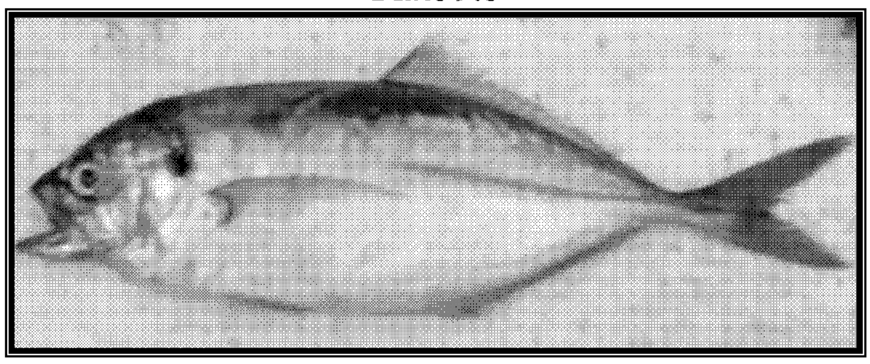


Mullus barbatus بربونى

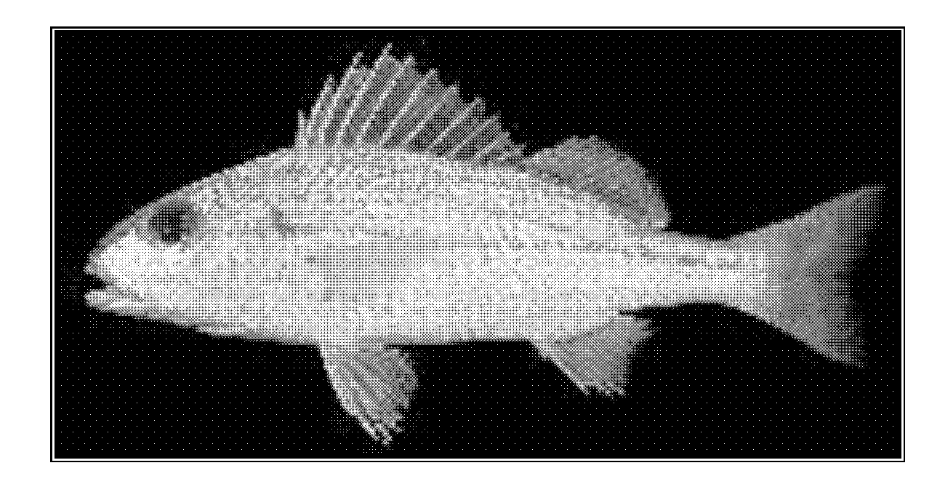


Mullus surmuletus بربونى

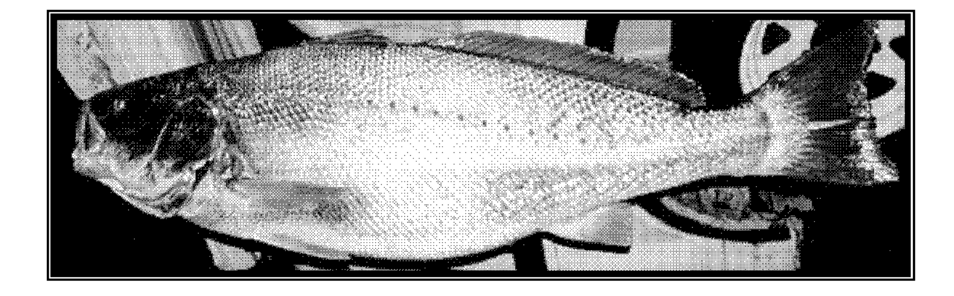
Plate 9.6



Caranx rhonchus شنيور

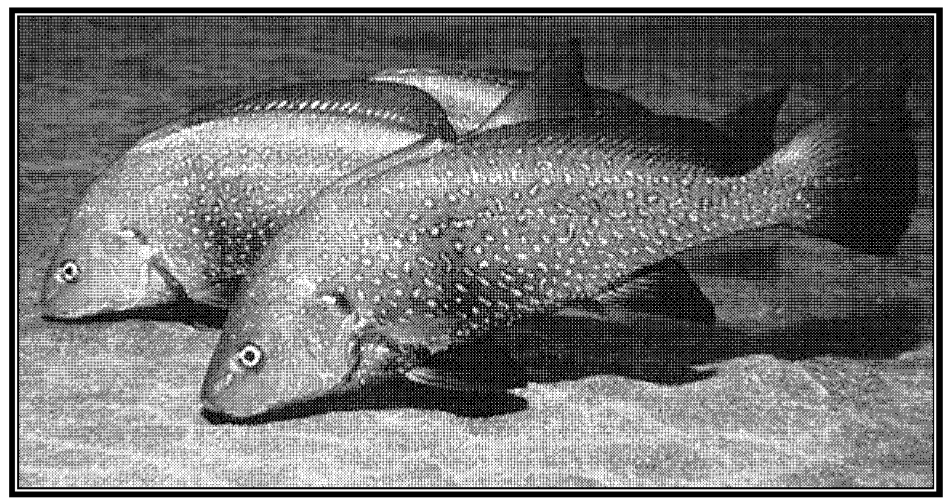


Pomadasys stridens باميا

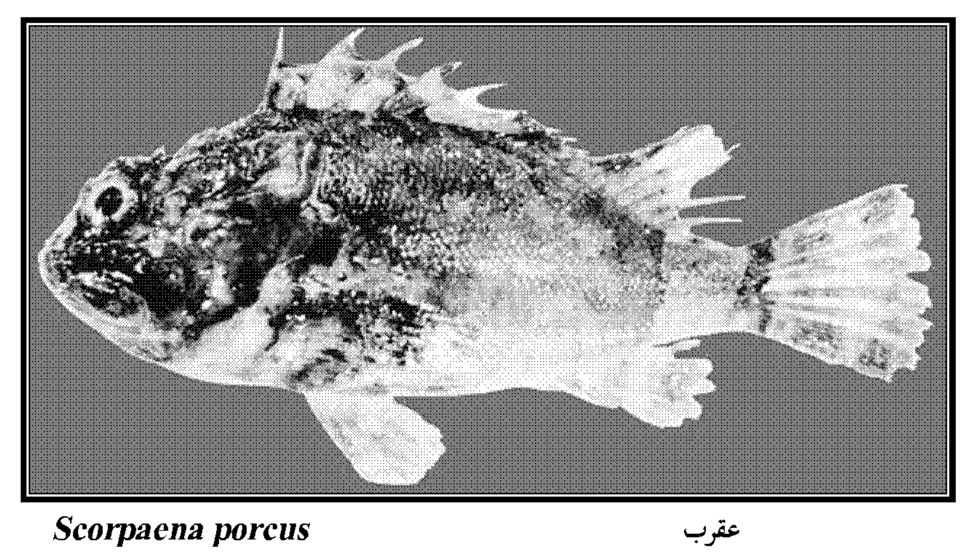


Argyrosomus regius لوت

Plate 9.7

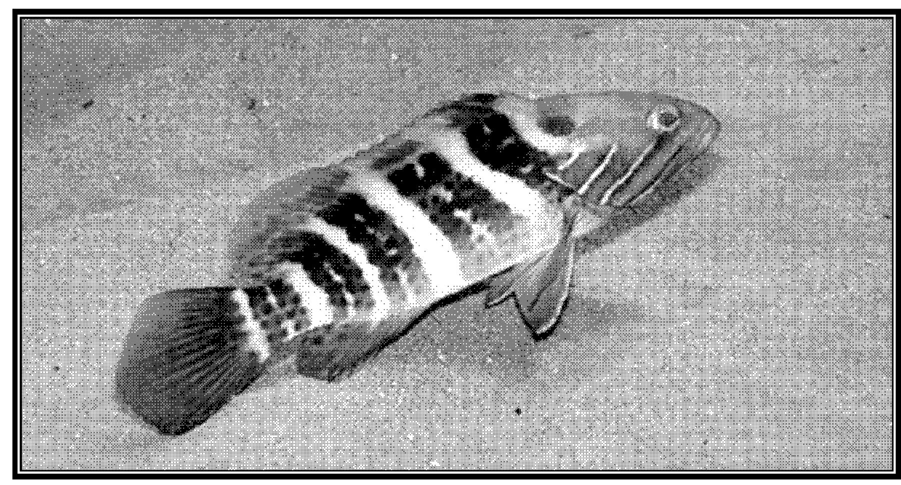


Umbrina cirrosa شفش

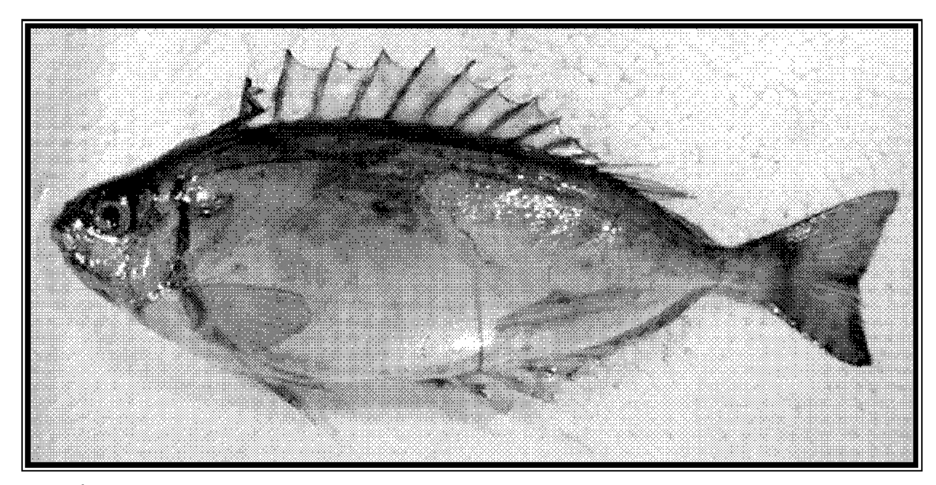


Scorpaena porcus عقرب

Plate 9.8

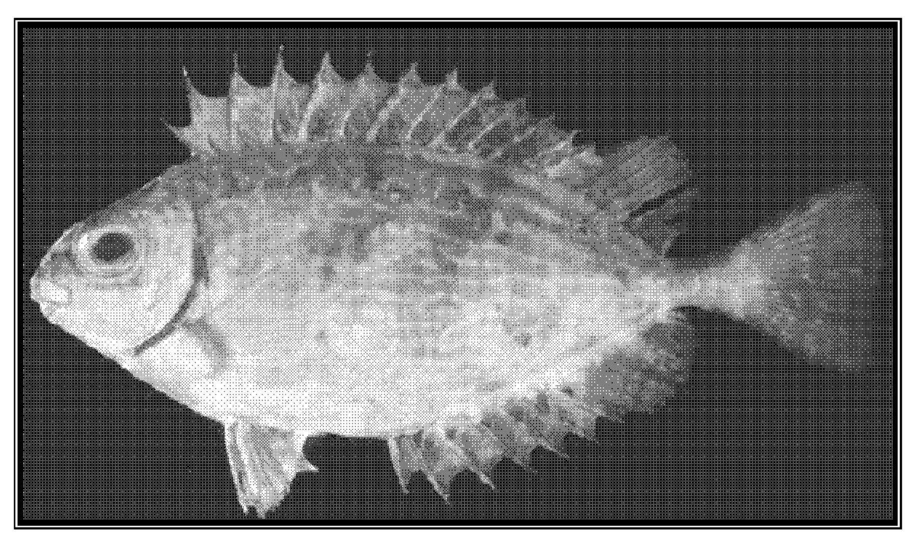


Epinephelus aeneus وقار

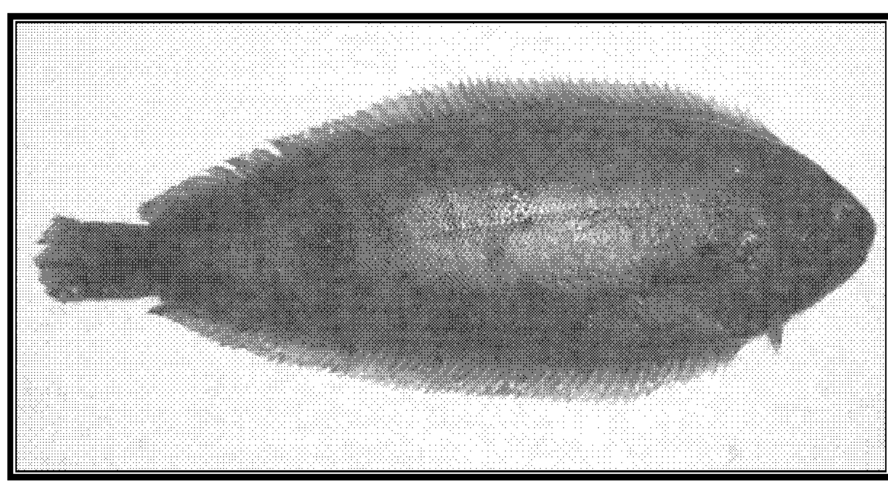


Siganus rivulatus سيجان

Plate 9.9

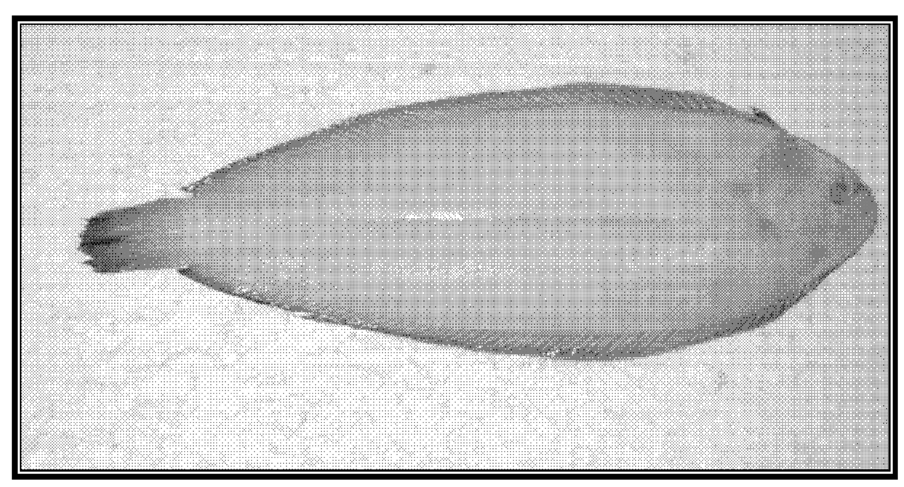


Siganus luridus سيجان

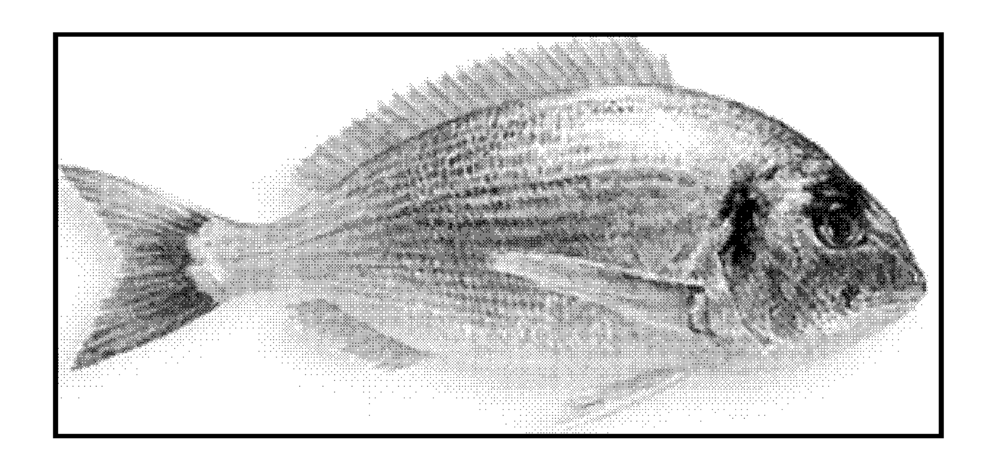


Solea solea موسى

Plate 9.10

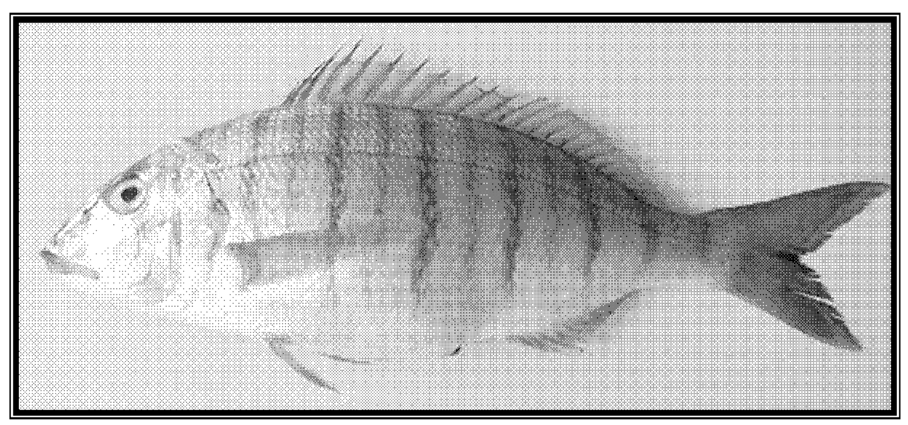


Solea aegyptiaca موسى

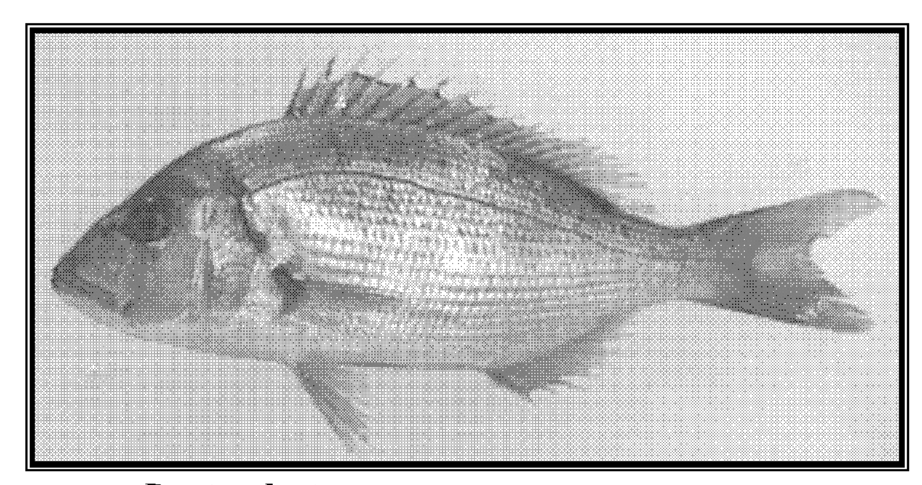


Sparus aurata دنيس

Plate 9.11

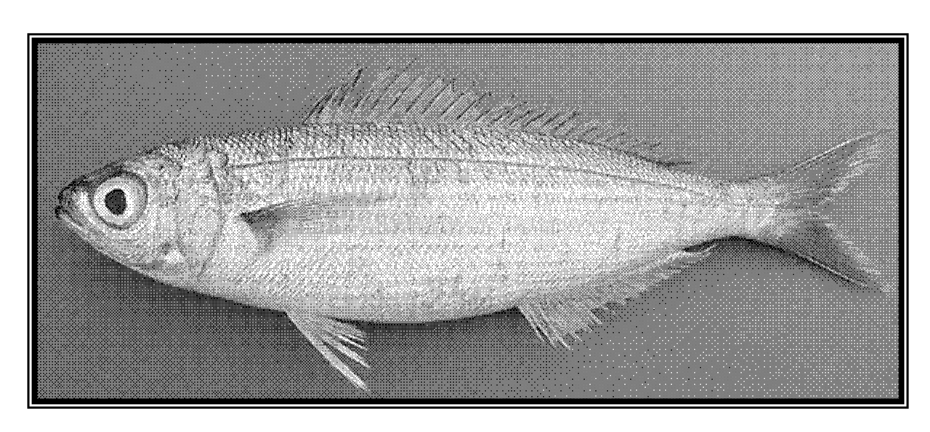


Lithognathus mormyrus غزيلة

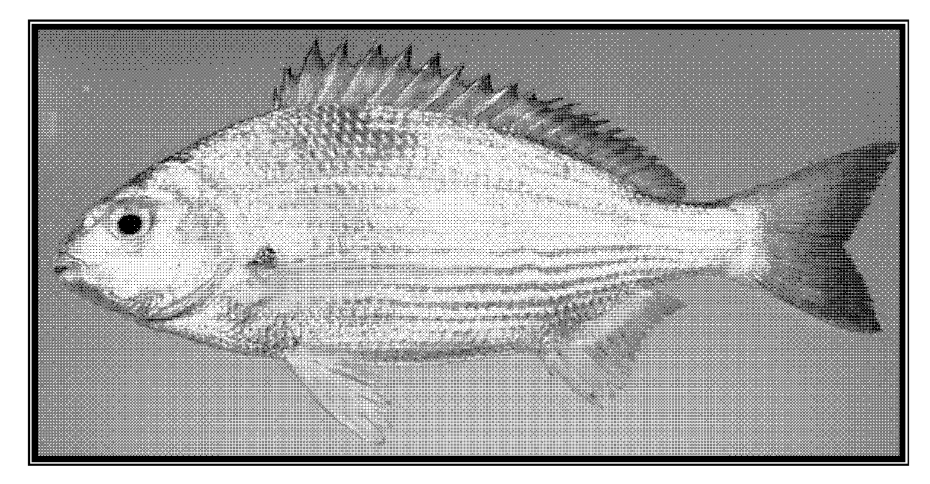


Dentex dentex عضاض

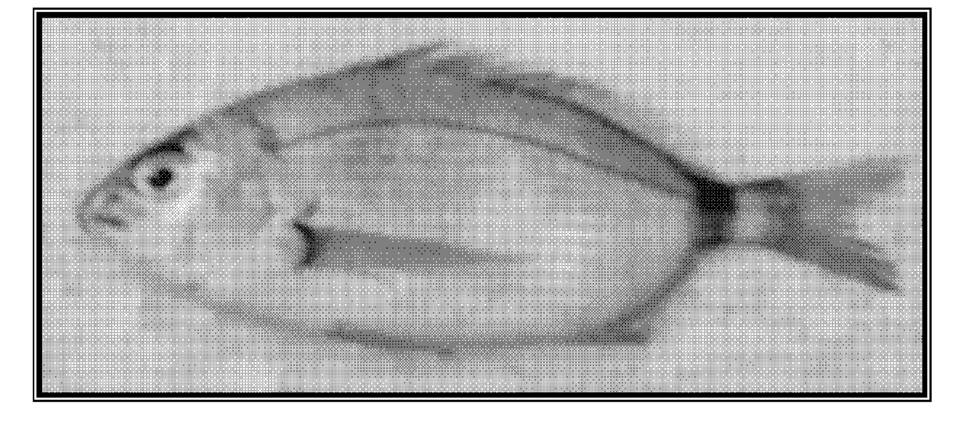
Plate 9.12



Boops boops موزة

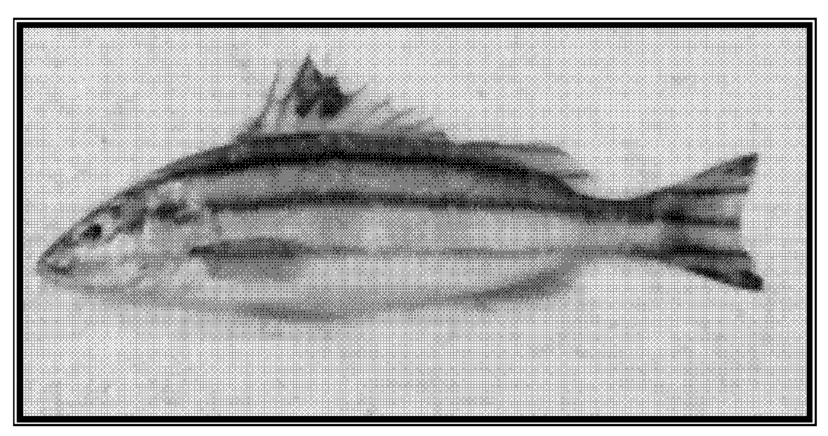


Crenidens crenidens موزة

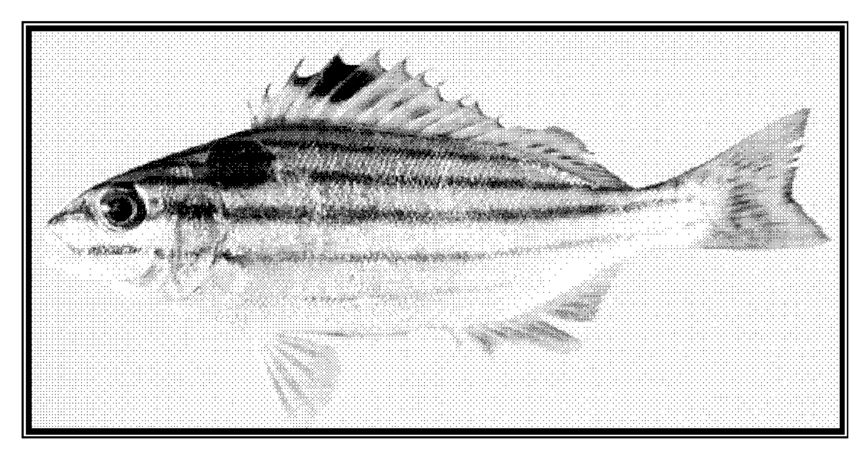


Diplodus annularis شرغوش

Plate 9.13

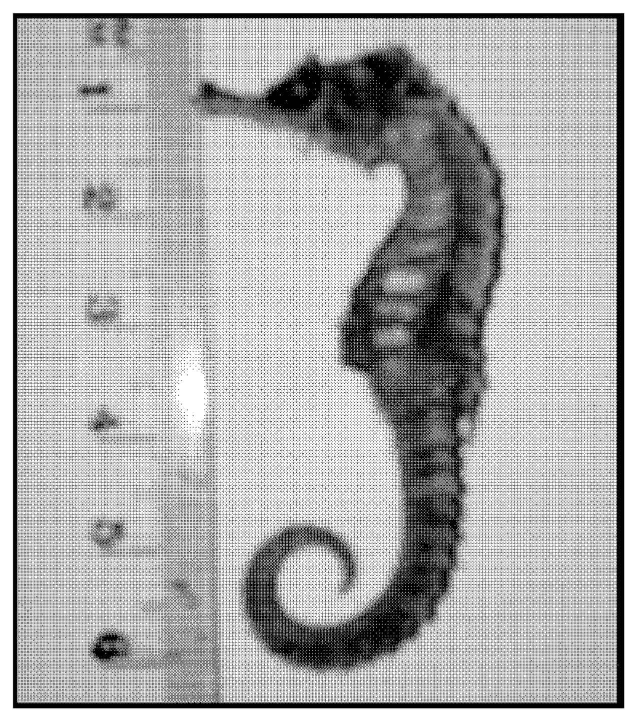


Terapon puta باميا

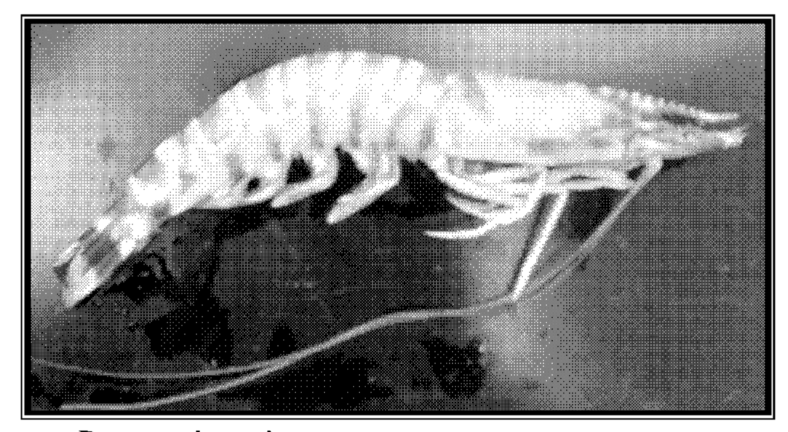


Pelates quadrilineatus جربوع

Plate 9.14

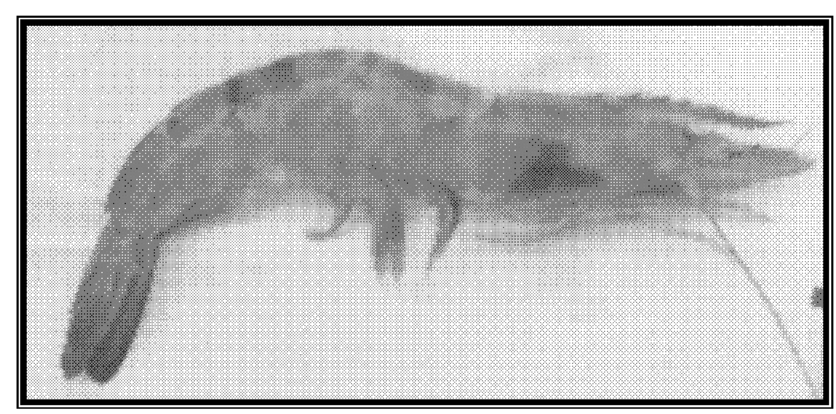


Hippocampus fuscus حصان البحر

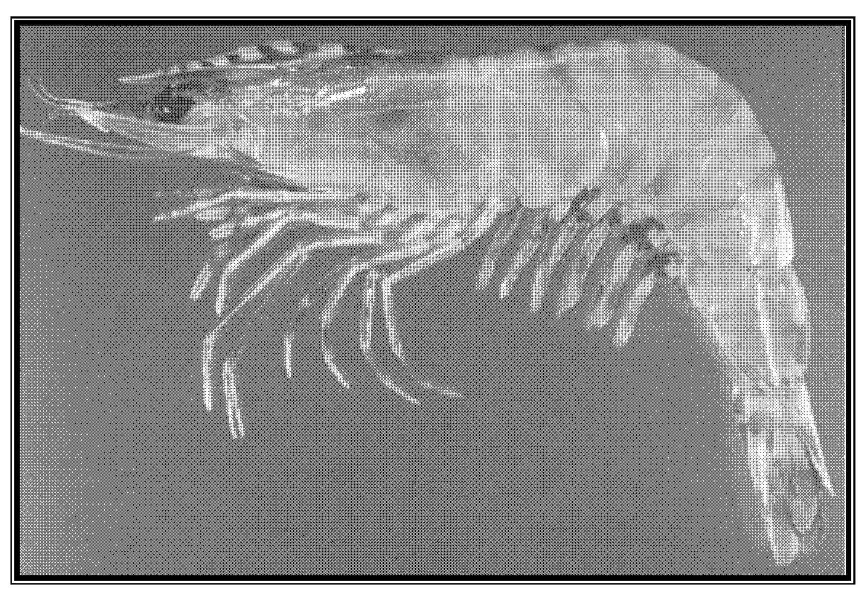


Penaeus japonicus جمبرى ياباني

Plate 9.15

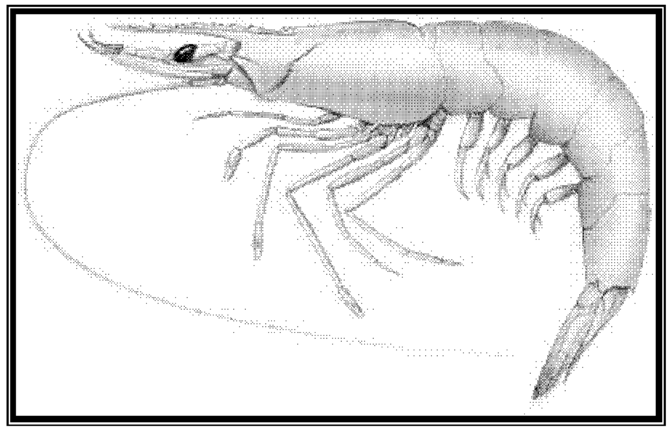


Penaeus kerathurus جمبرى قزازي

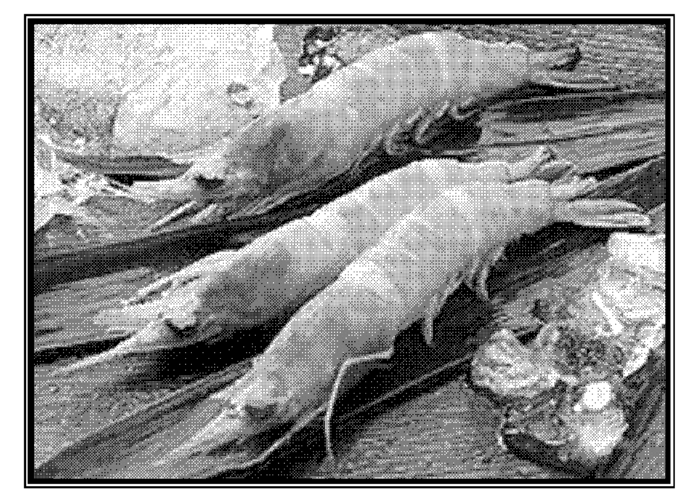


Penaeus semisulcatus جمبري سويسي

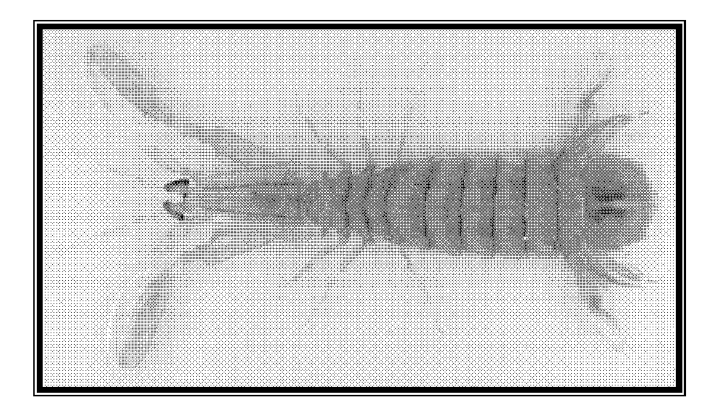
Plate 9.16



Metapenaeus stebbingi جمبرى أبيض

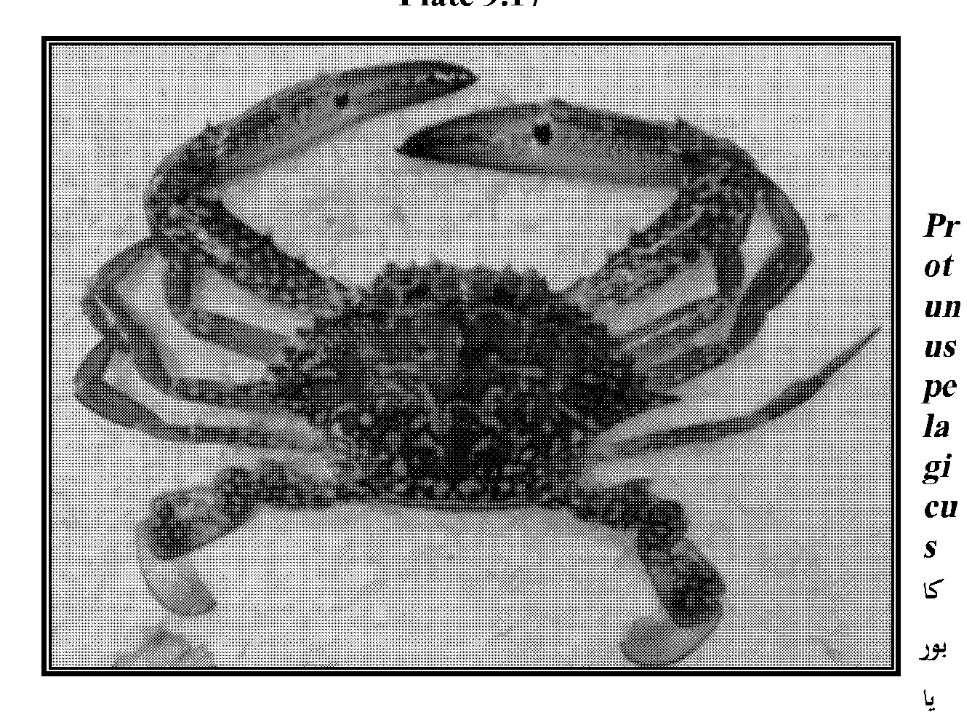


Trachypenaeus curvirostris جمبرى أبو ليفة

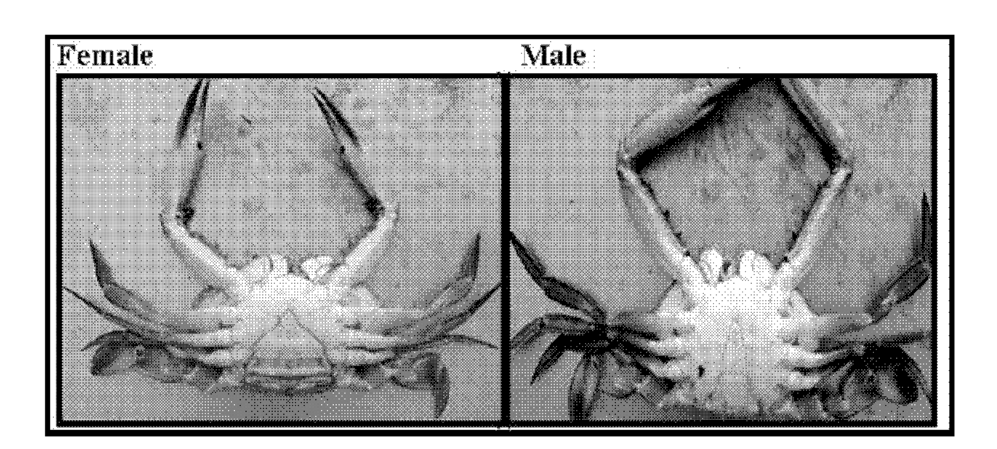


Erugosquilla massavensis شیکال

Plate 9.17

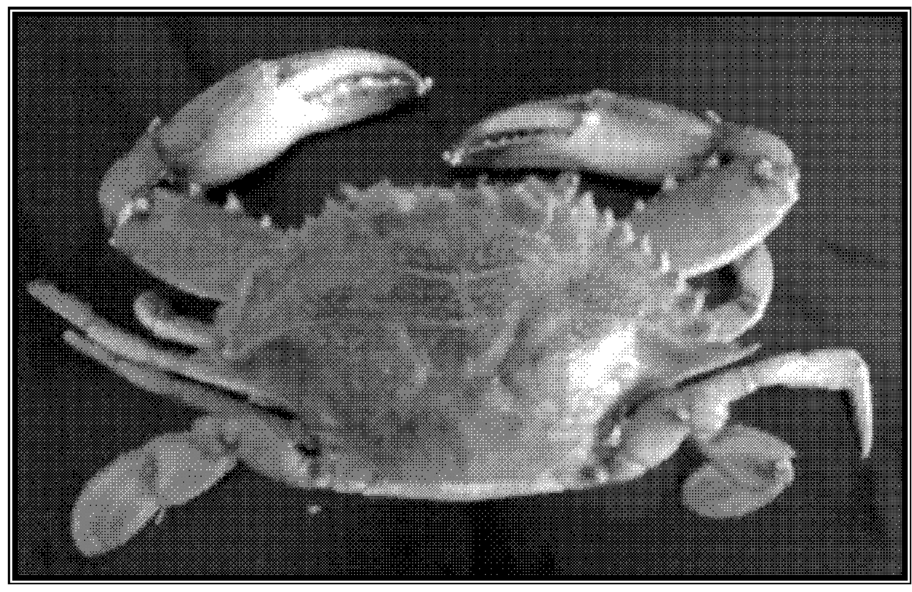


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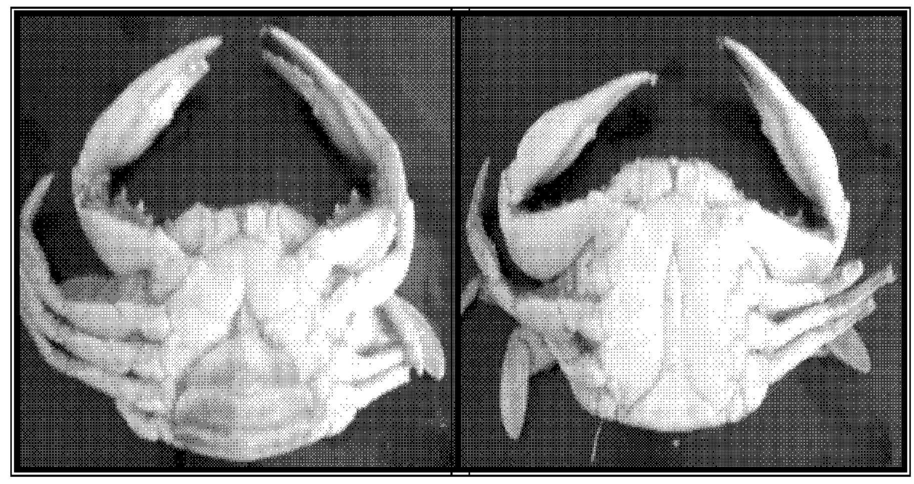


(ventral view)

Plate 9.18



Callinectes sapidus (dorsal view) كابوريا حجاري



Female Male

(ventral view)

Chapter 10
Arachnida and Insecta

10.1 ARACHNIDA

Fifty five spiders and scorpions, belonging to 3 orders were recorded in Bardawil area and Zaranik Protectorate during 2000 (El- Hennawy 2000). This survey is considered the first one in Bardawil area, and the species here mentioned are recorded for the first time from this region. El- Hennawy (2000) selected 13 sites to represent different habitats in the studied area (Table 10.1).

Table 10.1. **The 13 sites of the Arachnida study in Badawil Wetland (El-Hennawy 2000).**

Site	Location	Latitude (N)	Longitude (E)	Alt.
1	Visitors Centre	31° 04' 34"	33° 27' 57"	16 m
2	North east of Visitors Centre	31° 04' 39"	33° 28' 08"	24 m
3	North west of Visitors Centre	31° 04' 39"	33° 27' 47"	22 m
4	Fishermen Village	31° 08'05"	33° 28' 18"	14m
5	Sand Bar between lake and sea	31° 08'32"	33° 28' 39"	4m
6	Boughase I	31° 09' 03"	33° 27' 05"	
7	Boughase II	31° 08' 25"	33° 28' 03"	
8	El-Mahasna Island	31° 10' 06"	33° 20' 54"	
9	El-Matli Island	31° 06' 34"	33° 26' 22"	
10	El-Flousiyat Island 1	31° 07' 04"	33° 26' 11"	15m
11	El-Flousiyat Island 2	31° 07' 05"	33° 26' 21"	13m
12	El-Flousiyat Island 3	31° 07' 13"	33° 26' 13"	16m
13	El-Khoweinat	31° 06' 15"	33° 24' 33"	20m

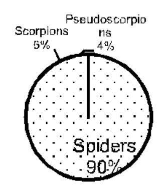


Fig. 10.1. **Percentage of collected specimens of Arachnida orders in Zaranik Wetland (El-Hennawy 2000)**

The percentage of collected specimens of Arachnida orders is indicated in Fig. 10.1. Spiders represent 89% of the total arachnids, followed by scorpions (6%) and pseudoscorpions (5%).

10.1.1 Order Araneida (Spiders)

Spiders of 20 families were collected from 13 sampled sites (Fig. 10.2). The dominant families were Liocranidae, Salticidae, Lycosidae and Gnaphosidae. Collecting sites [3, 2 & 1] near the Visitors Centre were the first sites in number of spider taxa and individuals. The first two of them are the best sites to be studied further and they are appropriate for ecological monitoring programs.

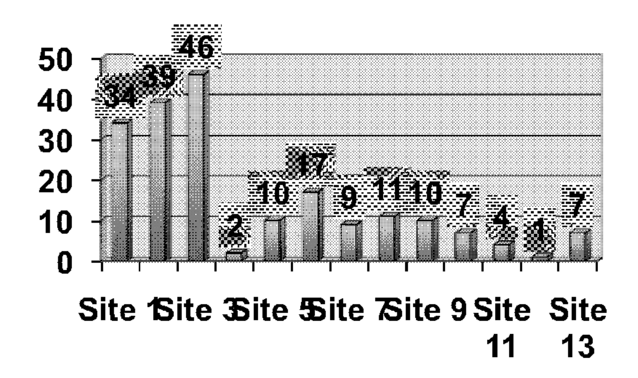


Fig. 10.2. **Number of spider specimens collected for each of the 13 sites in Zaranik Wetland (El-Hennawy 2000).**

10.1.1.1 Family Agelenidae

Adults and juveniles of *Agelena lepida* were found in collecting sites [1,2,3 & 11] in August, October and November 2000. Females and juveniles were found in their webs on plants and males were always in pitfall traps. Half of the number of collected specimens was from collecting site [2]. *Agelena lepida* was recorded from Siwa Oasis, Upper Egypt, Wadi El-Raiyan and Wadi Natron (El-Hennawy 2000).

10.1.1.2 Family Araneidae

Two females of *Argiope lobata*, were found in the morning, inverted in the hub of her orbweb, among almost dry herbs in collecting sites [6 & 10] in October and August, respectively. A juvenile specimen of the same genus was

found among plants in site [2] in August.Two silvery juveniles of *Cyclosa* were found in their orbwebs, vertical among herbs, in site [3] in October.

In October, at sites [5 & 6] many small orbwebs were noticed, but no spiders could be collected. *Argiope lobata* was recorded from Alexandria, Cairo, Sinai, Wadi El-Raiyan; one species of *Cyclosa* was recorded from Siwa and Wadi Natron.

10.1.1.3 Family Clubionidae

In site [2] a female *Cheiracanthium* sp. was found inside an empty *Stegodyphus* nest and a male *Cheiracanthium canariense* was pitfall trapped in August. A juvenile of the same genus was found in its nest on a plant in site [6] in October.

Two males of another clubionid species was found at collecting site [2] in November pitfall traps. A similar juvenile was found under a stone in a very wet land at site [4] in August. A female of another genus was found in site [6] in October.

Seven species of *Cheiracanthium* were recorded from: Alexandria, Asswan, Cairo, Siwa Oasis, Wadi El-Raiyan and Wadi Natron. There are many unpublished records of this genus from different regions of Egypt. It is now under revision (El- Hennawy 2000).

10.1.1.4 Family Eresidae

A female *Stegodyphus lineatus* with her spiderlings were found inside their nest on *Nitraria* shrub at site [2] in August. There were other similar nests; some of them small and empty, inhabited by other spider species. In the same area, in October, there were many nests containing single juvenile on green herbs. In site [3], in October, the dry remnant of a dead female *S. lineatus* was found inside her nest after the emergence of the spiderlings. A small juvenile nest was observed near the mother's nest in addition to other similar nests in the area. *Stegodyphus lineatus* was recorded from Alexandria, Cairo, Damietta, Sinai, Siwa Oasis and Suez (El- Hennawy 2000).

10.1.1.5 Family Gnaphosidae

Adult males, a female and juveniles of *Pterotricha lesserti* were collected from collecting sites [1, 2, 5, 8, 10 & 13] in August, October, and November: light attracted, free wandering, under stones or were pitfall trapped. Adults and juveniles of *Zelotes* sp. were collected from collecting sites [2, 3, 7, 8 & 10] in August, October, and November: free wandering, under stones or pitfall trapped.

In collecting site [2], a juvenile specimen was found inside an empty *Stegodyphus* nest in August. In collecting site [10], a female specimen was

found inside a salticid nest in August. It's an eggs eater spider (feeding on a salticid female spider's eggs).

Other gnaphosid species were found running on the ground in collecting sites [3 & 6] in August and October. Seven species of *Pterotricha* were recorded from: Alexandria, Aswan, Cairo, Giza, Siwa Oasis, Suez, Wadi El-Raiyan, Wadi Halfa. *Pterotricha lesserti* was recorded from El-Arish by Levy (1995). Ten species of *Zelotes* were recorded from Alexandria, Cairo, S.Sinai Siwa Oasis.

10.1.1.6 Family Linyphiidae

A female specimen was found in a pitfall trap in collecting site [3] in November. Seven genera of Linyphiidae were recorded from: Alexandria, Cairo, El-A'asher-Min-Ramadan, Wadi Natron

10.1.1.7 Family Liocranidae

Males and females of an unidentified species were abundant in pitfall traps in collecting sites [2 & 3] in August. A few specimens were found in October and November in both sites. Juveniles of another species were found in collecting site [5] in October under stones and plants. Two species of the liocranid genus *Mesiotelus* were recorded from Alexandria.

10.1.1.8 Family Lycosidae

Two males were light attracted at night and another male was trapped in a dipteran trap in collecting site [1] in August. Another male was pitfall trapped in site [3] in the same month. Several juveniles were collected in sites [1 & 2] in October and November inside a building, under stones, and in a pitfall trap.

In collecting sites [4] a female was found under a stone in a very wet habitat in August. In collecting sites [5, 6 & 7] females and juveniles were found running on ground among plant debris or pitfall trapped in October. Subadult males and females and juveniles were found in collecting site [8] in November under wet algae remnants. Lycosidae species were recorded from most habitats in several regions of Egypt.

10.1.1.9 Family Nemesiidae

A juvenile specimen of uncertainly identified Mygalomorph family was found among plants in collecting site [3] in October. One species of Nemesiidae was earlier recorded from Alexandria.

10.1.1.10 Family Oonopidae

A male was found in a dipteran trap in collecting site [1] in August. Four genera of Oonopidae were recorded from Ain-Musa, Alexandria, Siwa Oasis.

10.1.1.11 Family Philodromidae

Two male specimens of genus *Thanatus* and genus *Ebo* were pitfall trapped in collecting site [3] in August. Six species of *Thanatus* were earlier recorded from: Alexandria, Cairo, S. Sinai, Siwa Oasis, Wadi El-Raiyan. *Ebo* was recorded from Wadi El-Raiyan.

10.1.1.12 Family Pholcidae

Adults and juveniles of an unidentified genus were found in collecting sites [2 & 3] in August and October. Females and juveniles were found in their webs on plants and a male in a pitfall trap. Pholcidae were recorded from Alexandria, Cairo, S. Sinai, Siwa Oasis, Wadi Natron.

10.1.1.13 Family Salticidae

Adults and subadults of *Menemerus animatus* were found in collecting sites [1 & 13] in August and November inside buildings or pitfall trapped, and once light attracted.

Mogrus females were found in their webs on plants in collecting sites [7 & 11] in August and October (with recently hatched eggs in August). Many *Mogrus* nests were found empty, after the emergence of the spiderlings in collecting site [5] in October. A female and juveniles of *Plexippus paykulli* were found inside building in collecting sites [1] in November.

Several unidentified genera and species were found in collecting sites [1, 2, 3, 5, 6, 7, 9 &10] in August and October, either in their webs, free wandering, light attracted, under stones, or pitfall trapped.

Menemerus animatus was recorded from: Alexandria, Cairo, Siwa Oasis, Upper Egypt, Wadi Natron. It was found also in Ras El-Barr (unpublished record). Two species of *Mogrus* were recorded from: Alexandria, Siwa Oasis, Upper Egypt, Wadi El-Raiyan, Wadi Natron (unpublished records of this genus are from southern Sinai and Ras El-Barr). *Plexippus paykulli* was recorded from: Alexandria, Cairo and S. Sinai.

10.1.1.14 Family Scytodidae

A juvenile specimen of *Scytodes* was found wandering at night on a wall inside a building in collecting site [1] in November. Five species of *Scytodes* were recorded from Alexandria, Cairo, El-Fayum, Luxor, Siwa Oasis, Wadi Halfa and Wadi Natron.

10.1.1.15 Family Sparassidae

A juvenile specimen was found wandering at night (light attracted) on a wall of a building in collecting site [1] in November. Five genera of Sparassidae were recorded from Aswan, Cairo, El-Fayum, Fayed, Nubia, Port Said, Sinai, Siwa Oasis and Wadi Natron.

10.1.1.16 Family Tetragnathidae

A juvenile specimen was found on a cultivated plant in collecting site [1] in August. In collecting site [9], a subadult male and juveniles were found on herbs in October. Two genera were recorded from Alexandria, Cairo, El-Manzala, Nile Delta, Rosetta, Siwa Oasis, Wadi El-Raiyan and Wadi Natron.

10.1.1.17 Family Theridiidae

In collecting site [1] five females and a juvenile were found inside a lamp place, and a female was found in her web on a dry fig leaf (on the plant) in August, and both a male and a female were found in their webs inside a building in November.

In collecting site [8] a subadult male and a juvenile were found in their webs on dry ground, under green herbs in November. In collecting site [12] a subadult male was found on a thorny bush in August. In collecting site [13] a female and a juvenile were found among stones in August. Theridiidae were recorded from different regions of Egypt (El- Hennawy 2000).

10.1.1.18 Family Thomisidae

A juvenile specimen of *Thomisus* was found on melon's flower in collecting site [2] in August. A juvenile specimen of *Xysticus* was found under stone in collecting site [10] in August. Four species of *Thomisus* were recorded from Aswan, Cairo, El-Arish, El-Baharia Oases, Kom Ombo, Kom Osheem, Nuweiba, Ras El-Barr, St.Katherin, Siwa Oasis, Wadi El-Raiyan, Wadi Natron. Seven species of *Xysticus* were recorded from: Alexandria, Cairo and S. Sinai.

10.1.1.19 Family Uloboridae

A female and a juvenile of *Uloborus* were found in their webs among herbs in collecting site [2] in August. Another female was collected from the same area in October. Two species of *Uloborus* were recorded from Cairo to Assiut, Nile Valley and near Red Sea, and Siwa Oasis.

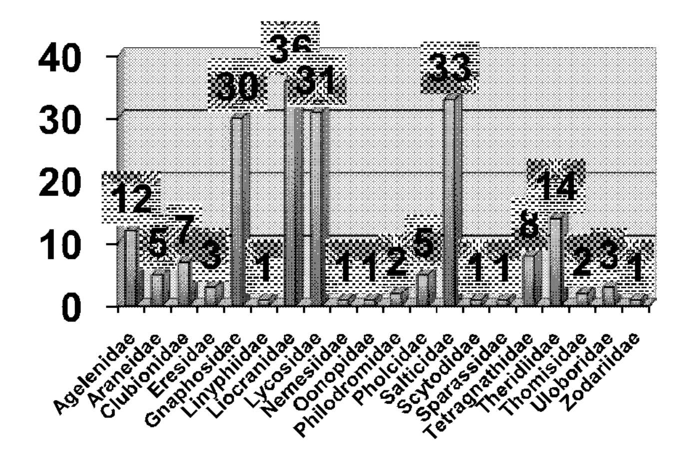


Fig. 10.3. **Number of collected specimens of each spider family in Zaranik area (El-Hennawy 2000).**

10.1.1.20 Family Zodariidae

A juvenile specimen of *Zodarion* was light attracted, at night, in collecting site [1] in October. Four species of *Zodarion* were recorded from Alexandria, Cairo, and Siwa Oasis.

Nine specimens of family *Olpiidae* were collected in August, October and November from collecting sites [2, 4, 6, 8, 9, 11 & 13], from under stones or wet algae remnants [8] and pitfall traps. A single specimen from collecting site [7] in October, may be from family *Chernetidae* .

Olpiidae species were recorded in Egypt from Aswan, Cairo, Giza, Luxor, Senafir Island (Red Sea), Wadi Halfa and Wadi Natron; two genera of Chernetidae were recorded from lower Egypt without definite locality.

10.1.2 Order Pseudoscorpionida (False Scorpions)

Nine specimens of family *Olpiidae* were collected in August, October and November from collecting sites [2, 4, 6, 8, 9, 11 & 13], from under stones or wet algae remnants [8] and pitfall traps. A single specimen from collecting site [7] in October, may be from family *Chernetidae* .

Olpiidae species were recorded in Egypt from Aswan, Cairo, Giza, Luxor, Senafir Island (Red Sea), Wadi Halfa and Wadi Natron; two genera of Chernetidae were recorded from lower Egypt without definite locality.

10.1.3 Order Scorpionida (Scorpions)

Three scorpion species of family Buthidae were recorded in this preliminary survey. All specimens were found under stones or in big pitfall traps in collecting sites [1 & 10] in August and October. Only one specimen of *Androctonus bicolor* was found at night inside a building in October.

Table 10.2. **Scorpions species recorded in Zaranik area during 2000 (El-Hennawy 2000).**

Species	Specimens	Sites	Month
Androctonus amoreuxi	2	10	Aug
Androctonus bicolor	2	10	Aug
	2	1, 10	Oct
Buthacus leptochelys	2	1, 10	Aug
	1, 4	1, 10	Oct

10.2 INSECTA

An early survey dealing with the insects of Egypt and Sinai goes back to Forskal (1775), who described 13 beetle species belonging to Egyptian fauna. His work was followed by the publication of the discoveries made during the nineteenth century by Olivier (1801-1807); Klug (1820-1825) who studied materials collected by Ehrenberg and Hemprich during their voyage in the Orient. Crotch (1865) listed 128 beetle species and described 15 new species,

when he examined the specimens collected by Captain Wilson and Palmer during their exploration of Sinai Peninsula. In 1891 Hart gave an account on insect fauna of Sinai Peninsula. Heyden (1899) studied the coleopterous materials that were collected by Prof. Koenig (Bonn) during his travel from Suez to Ghaza.

In the twentieth century Kneucker (1903) listed 75 insect species from Sinai, and Peyerimhoff (1907) reported 300 species of beetles from Sinai (17 species were new records) during his voyage in February and March 1902. He noted the zoogeographical distribution of each species in Sinai and globally. Boyd (1917), during his participation with the Egyptian Expeditionary Force on the Suez Canal and later in the North of Sinai along the north road from El-Qantara to El-Arish, recorded 331 insects species, of which 126 were butterflies and moths only. He noted the localities of collection for each species and in some cases he gave the depository in which the specimens were preserved. Furthermore, Alfieri (1920) listed 86 insect species from North Sinai with their distribution, while Kneucker (1922) listed 60 beetle species from Sinai, and he recorded their geographical distribution and month of collection.

Bodenheimer (1932) during his survey in Sinai, listed 84 orthopteroid species, including 7 blatterian species, 15 species of Mantodea, 59 Orthoptera and 2 Dermaptera. Moreover, he gave zoogeographical analysis to the fauna and its affinities.

Efflatoun (1930-1945), a pioneer Entomologist in Egypt, published 6 parts of his excellent monograph "A Monograph of Egyptian Diptera". The monograph was based on the families Asilidae, Tabanidae, Tephritidae, Syrphidae and Bombyliidae (only the first half of the family). He surveyed many localities representing different ecological zones and habitats in Egypt. The Sinai Peninsula was exhaustively surveyed through his work, and many of the Egyptian species were represented from Sinai. Twenty five species representing 25% of the Egyptian Asilidae, 10 species representing about 30% of the Egyptian Tabanidae, 6 species representing 20% of the Egyptian Syrphidae, and 30 species representing about 25% of the Egyptian Bombyliidae.

Alfieri (1920, 1957 & 1976) collected numerous specimens of many orders of insects during his long career in Egypt (1909-1971); Coleoptera or beetles were his favorite order. He collected beetles all over the country, especially in desert, Sinai Peninsula, oases and other non-cultivated habitats. His great work on Coleoptera was published, after his death, in 1976. This work comprises a total of 2974 species of Coleoptera, belonging to 63 families and 827 genera. Almost all of them were collected and recorded from Egypt, including Sinai. He gave the geographical distribution and month of collection for each species, in addition to some information about synonyms and ecology of some species. Taha *et al.*(1984) listed insects from Southern Sinai, and Zalat

(1995) listed the species of orders Coleoptera and Hymenoptera that populate Sinai Peninsula in his report prepared to the Sinai desert training center.

El-Moursy & Mohamed (1997), through a national project for studying the biodiversity in Egypt, they produced 7 volumes on the biodiversity of insects in Egypt, zoogeographical distribution all over the country, abundance and habitat, in addition to the synonyms of each species.

Sinai peninsula generally, and north Sinai especially, is considered as a faunal bridge between Mediterranean elements to the north, Afrotropical species to the south, North African elements to the west, and Levant fauna to the east. Moreove,r Sinai has its unique habitats and its endemic species

The whole Northern Sinai, including Bardawil area, is an arid desert where the rainfall is relatively scarce. The annual average is 100 mm at El-Arish and only 80 at Telul. The area until very recently could maintain a very high degree of integrity, a unique social life based on grazing and agriculture, and a rather limited impact on the native biodiversity. During recent years, however, a dramatic change has occurred, threatening not only social life, but much of its ecosystems and the surrounding habitats. The single most threatening factor to biodiversity is touristic urbanization at the Mediterranean coast of Sinai; new touristic villages change the native ecosystem, and may at the end destroy the site itself. The second major impact is the production of salt through salt pans, which may change the soil quality at the production areas and its surroundings, and consequently changing the biodiversity of these habitats.

10.2.1 Species Composition

El-Moursy *et al.* (2000) carried out four entomological expeditions to Bardawil area, between August and November 2000; each lasted for four days. 19 sites were surveyed, yielding a total of 853 specimens. The area of investigation was divided into 7 zones;

Zone A: (stns. 1-6) is the area of the Visitors Center of the protected area .

Zone B: (stns. 7-10) includes fishermen settlements and all adjacent places .

Zone C: (stns. 11-12), is represented by the sandy bar at the north of the Lake; separating the Lake from the Mediterranean Sea. It is characterized with few scattered patches of *Z. album*.

Zone D: (stn. 13), includes all area of Khwyinat isle.

Zone E: (stns. 14-15), encompasses the area of Flossyiat isle that is characterized by sand dunes and different plant covers of *A. monosperma, R. reatam, P. turgidum, N. retusa* and *S. scoparia*.

Zone F: (stns. 16-18), includes islands in the lagoon, which are mainly mixed salt affected habitats. The most common plant cover is *Z. album*, *Halocnemum strobilaceum* (Pallas), and *Salicornia europaea*.

Zone G: (stn. 19), includes the Matli isle area, which is predominantly sand dune and mainly covered with *A. monosperma*, *R. reatam*, *P. turgidum*, *N. retusa* and *S. scoparia*.

El-Moursy *et al.* (2000) recorded 202 insect species belonging to 170 genera and 65 families and representing 16 orders in Bardawil area and Zaranik Protectorate (Tables 10.1 & 10.2).

Table 10.3. **Annotated checklist of the insect fauna, specimens, and status of species in Zaranik Protectorate (North Sinai) between August and November 2000 (El-Moursy *et al.* 2000).**

Order/ Family/ Genus	Species	Collected specimens	Status
BLATTARIA			
Blattidae			
Blattella	*arundinicola* Werner	6	Moderately common
Heterogamodes	*cerverae* Bolivar	30	Very common
Periplaneta	*americana* (L.)	3	Moderately common
Periplaneta	*tartara* Saussure	1	Rare
COLEOPTERA			
Anobiidae			
Lasioderma	sp.	1	Rare
Stegobium	*Panicum* (L)	15	Very common
Xylctinus	*bucephalus bucephalus* Illiger	2	Rare
Anthicidae			
Anthicus	*floralis* (L.)	1	Rare
Anthicus	sp.1	13	Moderately common
Anthicus	sp.2	10	Moderately common
Anthicus	sp.3	4	Moderately common
Anthicus	sp.4	1	Moderately common
Carabidae			
Cicindela	*aulica* Dejean	1	Rare
Cicindela	*litorea* Forskal	50	Very common
Megacephala	*euphratica* Lat.	3	Rare
Paussus	*thomsoni* Reiche	10	Rare Rare Moderately common
Pogonus	*gilvipes* Dejean	5	
Scarites	*guineensis* Dejean	10	
Syrdenus	*grayi* Wollaston	15	Very common
Tachys	*scutellaris* aegyptiacus Sen. &Koch	12	Common
Thermophilum	*sexmaculatum* pharaonum (Bedel)	10	Moderately common
Trichis	*maculatus* Klug	2	Rare
Cerambycidae			
Phytoecia	sp.	1	Very rare
Prionus	*aegyptiacus* Pic	20	Very common

Order/ Family/ Genus	Species	Collected specimens	Status
Cleridae			
Necrobia	*rufipes* (Degeer)	2	Common
Coccinellidae			
Coccinella	*undecimpunctata*	1	Common
Dermestidae *Attagenus*	sp.	3	Rare
Dermestes	*maculatus* Degeer	5	Common
Dytiscidae			
Eretes	*sticticus* L.	1	Very rare
Elateridae			
Isidus	letourneuxi Pic	1	Very rare
Histeridae			
Saprinus	sp.1	1	Rare
Saprinus	sp.2	2	Rare
Hydrophilidae			
Sternolophus Lathrididae	*solieri* Lapouge	1	Very common
Melanophthalma	*distinguenda* Comolli	2	Rare
Nitidulidae			
Nitidula *Nitidula*	*ciliata* Erichson sp.1	3 3	Moderately common Moderately common
Nitidula	sp.2	1	Rare
Oedemeridae			
G1	sp.	1	Very rare
Phalacridae			
Olibrus	*corticalis* Panzer	5	Moderately common
Ptinidae			
Ptinus	*soubironi* Pic	23	Very common
Scarabaeidae			
Aphodius	*dorsalis* Klug	3	Moderately common
Aphodius	*hydrochoereis* (Fabricius)	1	Rare
Aphodius	*lucidus* Klug	11	Very common
Aphodius	*pallescens* Walker	16	Very common
Aphodius	sp.	1	Rare
Onthophagus	*melanocephalus* Klug	4	Moderately common
Oryctes	*nasicornis* (L.)	3	Moderately common
Phyllognathus	*excavatus* Forster	35	Very common
Rhyssemus	*coluber* Klug	1	Rare
Scarabaeus	*cristatus* Fabricius	6	Moderately common
Trox	*squalidus* (Olivier)	1	Rare
Staphylinidae *Bledius*	*capra capra* Fauvel	26	Very common
Philonthus	sp.	1	Rare
Tenebrionidae			
Alphitobius	*diaperinus* Panzer	5	Moderately common
Blaps	*polychresta* Forskal	8	Common
Cataphronetis	*apicilaevis* Marseul	1	Rare

Order/ Family/ Genus	Species	Collected specimens	Status
Clitobius	*oblongiuscalus* lineicollis Fairmaire	1	Rare
Clitobius	*ovatus* Erichson	1	Rare
Mesostena	sp.	6	Common
Oterophloeus	*alreatus peyerimhoffi* Koch	10	Common
Phaleria	*prolixa aegyptiaca* Seidlitz	25	Common
Pimelia	*angulata sinaitica* Sch. & Koch	5	Common
Pimelia	*barthelemyi* Solier	9	Common
Prionotheca	*coronata* Olivier	12	Very common
Scaurus	*aegyptiacus* Solier	31	Very common
Scleron	sp.	1	Rare
Tentyrina	*orbiculata* Fabricius	5	Common
Zophosis	plana plana Fabricius	2	Rare
Throscidae			
Throscus	sp.	9	Common
DERMAPTERA			
Labiduridae			
Labidura	*confusa* Capra	9	Moderately common
DIPTERA			
Asilidae			
Apoclea	*femoralis* Wiedemann	2	Moderately common
Nemochtherus	*clypeatus* Becker	5	Moderately common
teolophonotus	*molitor* Wied.	2	Moderately common
Promachus	*griseiventris* Becker	7	Very Common
Bombyliidae *Exhyalanthrax* *Petrorossia*	 sp. sp.	 1 2	 Rare Rare
Spogostylum	*candidum* (Sack)	2	Rare
Chironomidae			
Cricotopus	*mediterraneus*	7	Very Common
Culicidae			
Culex	*pusillus* (Macquart)	12	Very Common
Ephydridae			
Actoecetor	*margaritatus* Wied.	7	Very Common
G1	sp.	5	Moderately common
G2	sp.	4	Moderately common
Notiphila	setigera Bick.	5	Common
Muscidae			
Musca	*albina* Wied.	1	Rare
Musca	*domestica* L.	10	Very common
Musca	sp.	1	Rare
Otitidae			
Physiphora	*alcae* (Preyssler)	2	Very Common
Dhysiphora	*smaragdina* Loew	3	Very Common
Sarcophagidae			
Wohlfahrtia	*villeneuvi* Sal.	1	Moderately common
Stratiomyidae			

Order/ Family/ Genus	Species	Collected specimens	Status
Nemotelus	*albifascies* Bick	4	Common
Syrphidae			
Syrphus	*corollae* Fabricius	4	Moderately common
Tabanidae			
Ochropus	*agrestis* Wied.	2	Common
Tabanus	*albifacies* Loew	3	Rare
Tachinidae			
Actia	*crassicornis* (Meigen)	3	Moderately common
Eurithia	*castellana* (Strobl)	1	Moderately common
Exorista	*arvarum* (L.)	1	Moderately common
G1	sp.	1	Moderately common
Temorilla	*floralis* (Fallen)	1	Moderately common
Siphona	*efflatouni* Mesnil	1	Moderately common
Therevidae			
Neothereva	*angustifrons* Krob.	1	Rare
Psilocephala	*frauenfeldi* Loew	1	Rare
EMBIOPTERA			
Oligotomidae			
Oligotoma	*nigra* Hagen	2	Rare
HETEROPTERA			
Cydnidae			
Geotomus	*ntrusus* Wagner	7	Common
Macroscytus	*jrunneus* (Fieber)	8	Common
Lygaeidae			
G1	sp.	1	Moderately common
Geocoris	*henoni* Puton	2	Moderately common
Lamprodema	*maurum* Fabricius	1	Moderately common
Nysius	*cymoides* (Spinola)	2	Moderately common
Pachybrachius **Miridae**	*annulipes* (Bar.)	3	Moderately common
Campylomma	sp.	1	Moderately common
Lygus	*apicalis* Fieber	2	Moderately common
Tuponia	lethierryi Reuter	1	Moderately common
Tuponia	sp.	1	Moderately common
Pentatomidae			
Acrosternum	*heegeri* (Fieber)	1	Common
Acrosternum	*millieri* (Mulsant & Rey)	1	Rare
Choarntha	*ornatula* (H-Sch.)	22	Very common
Mecidea	*lindbergi* Wagner	1	Common
Rhopalidae			
Liorhyssus	*hyalinus* Fabricius	1	Moderately common
HOMOPTERA			
F1			
G1	sp.	1	Moderately common
F2			
G1	sp.	1	Rare
HYMENOPTERA			

Order/ Family/ Genus	Species	Collected specimens	Status
Evaniidae			
Evania	*dimidiata*	1	Moderately common
Formicidae			
Camponotus	*maculatus*	7	Common
Camponotus	*oasium* Forel	108	Very Common
Cardiocondyla	sp.1	6	Moderately common
Cardiocondyla	sp.2	8	Moderately common
Cataglyphis	*diehlj* (Forel)	7	Moderately Common
Cataglyphis Cataglyphis	*lividus* (Andre) *niger* (Andre)	29 6	Very Common Moderately Common
Crematogaster	*aegyptiacus* Mayr	53	Very Common
Messor	*aegyptiacus* Emery	2	Rare
Messor	*ebininus* Santschi	1	Rare
Monomorium	*carbonarium* (Smith)	9	Moderately Common
Monomorium	niloticum Emery	7	Moderately common
Pheidole	*katonae* Forel	77	Very Common
Pheidole	sp.	5	Moderately common
Ichneumonidae			
G1	sp.	1	Rare
Mutillidae			
G1	sp.	3	Rare
G2	sp.	3	Rare
Pompilidae			
G1	sp.	2	Rare
LEPIDOPTERA			
Arctiidae			
Utetheisa	*pulchella* L.	3	Moderately common
Noctuidae			
Agrotis	*lerzogi* Rebel	1	Moderately common
Agrotis	*pselon* (Hufnagel)	1	Moderately common
Armada	sp.	3	Moderately common
Autographa	*gamma* L.	2	Rare
Earias *Gram modes*	*insulana* (Boisduval) *boisdeffrei* Oberthur	3 6	Moderately common Very common
Helicoverpa	*armigera* Hubner	7	Common
Leucanitis *Mythemna*	*kabyfaria* *loryei* Duponchel	2 5	Rare Moderately common
Noctua	*floralis* H.	1	Moderately common
Noctua	*pronuba* L.	1	Rare
Ophiusa	*tirhaca* Cramer	2	Rare
Plusia	sp.	1	Rare
Polia	sp.	5	Rare
Propsalta	sp.	1	Rare
Protoschinia	sp.	2	Rare
Spodoptera Spodoptera	*exigua* (Hubner) *littoralis* Boisduval	6 1	Moderately common Moderately common
Pyralidae			

Order/ Family/ Genus	Species	Collected specimens	Status
Anerastia	*nitidicostella* Ragonot	9	Very common
Antigastra	sp.	1	Rare
Nephoterix	*cleopatrella* Ragonot	1	Rare
Nomophila	*noctuella* D. & Sen.	12	Common
Syria	*pilosella* Zeller	3	Rare
Sphingidae			
Agrius	*convolvuli* L.	1	Common
Macroglossum	*stelltarum* L.	1	Common
Tineidae			
Trichophaga	*abruptella*	1	Moderately common
Trichophaga	*tapetzella* L.	2	Moderately common
MANTODEA			
Mantidae			
Blepharobsis	*mendica* (Fabricius)	7	Common
Emeles	*aegyptiaca* Werner	6	Common
Iris	*orlatoria* (L.)	1	Very rare
Reivetina	*fasciata* (Thunberg)	1	Common
NEUROPTERA			
Chrysopidae			
Chrysoperla	*carnea carnea* (Stephens)	6	Moderately common
Myrmelionidae			
Creoleon	*antennatus* (Navas)	4	Common
Cueta	*lineosa* (Rambur)	6	Common
G1	sp.	3	Moderately common
Gepus	*curvatus* Navas	5	Common
Gepus	*invisus* Navas	9	Common
Myrmecaelurus	*laetus* (Klug)	6	Common
Neoclisis	*lineata* Navas	15	Very common
Teurleon	*ugubris*	7	Common
Phanoclisi	*ongicollis*	5	Common
Pseudoformicales	*nobilis* Navas	6	Common
ODONATA			
Aeschnidae			
Anax **Coenagriidae**	*parthenope* (Selys)	1	Very rare
Ischnura	*senegalensis* (R.)	2	Rare
Libellulidae *Crocothemis*	*erythraea* Brulle	3	Rare
ORTHOPTERA			
Acrididae			
Hyalorhipis	*rhamses* Saussure	1	Moderately common
Leptopternis	*gracilis* (Eversmann)	1	Moderately common
Platypterna	*gracilis* Krauss	2	Rare
Tryxalis	*nasuta* (L.)	1	Moderately common
Gryllidae			
Gryllodes	*sigillatus* (Walker)	1	Rare
Gryllomorpha	*rufescens* Uvarov	13	Very common

Order/ Family/ Genus	Species	Collected specimens	Status
Gryllopsis	*mareoticus* (Warner)	1	Rare
Gryllus	*bimaculatus* Degeer	6	Moderately common
Modicogryllus	*algericus* (Saussure)	5	Common
Modicogryllus	*palmetorum* (Krauss)	2	Rare
Stenonemobius	*gracilis* (Jakovlev)	3	Rare
Pyrogomorphidae			
Pyrogomorpha	sp.	1	Moderately common
SIPHONAPTERA			
F1			
G1	sp.	1	Rare
STREPSIPTERA			
Mengenillidae			
Mengenilla	sp.	1	Very rare
THYSANURA			
F1			
G1	sp.	2	Common
G2	sp.	4	Common
G3	sp.	5	Common

32.18 % of known faunal richness is accounted for by only one insect order; Coleoptera or beetles (65 species), although 15 other orders are represented in the fauna. Diptera or flies (15.35%), Lepidoptera (13.86%), Hymenoptera (Ants, wasps and bees) (9.41%), Heteroptera or bugs (7.92%), Orthoptera or crickets, grasshoppers and locusts (5.94%), Neuroptera or ant-lions and aphid-lions (5.45%). The other insect orders made up 7.92% of all recorded orders.

Within 202 species, there are 29 species (14.36%) very common, 39 species (19.31%) are common, 67 species (33.17%) are moderately common, and 60 are rare species (29.70%), 7 species (3.47%) are very rare.

Table 10.4. **Insects taxa recorded at Bardawil area (North Sinai) between August and November 2000 (El-Moursy *et al.* 2000)**

Order		Family	Genera	Species
Blattaria		**1**	**3**	**4**
Coleoptera		**20**	**51**	**65**
Dermaptera		**1**	**1**	**1**
Diptera		**13**	**28**	**31**
Embioptera		**1**	**1**	**1**
Heteroptera		**5**	**14**	**16**
Homoptera		**2**	**2**	**2**
Hymenoptera		**5**	**12**	**19**
Lepidoptera		**5**	**25**	**28**
Mantodea		**1**	**4**	**4**
Neuroptera		**2**	**10**	**11**
Odonata		**3**	**3**	**3**
Orthoptera		**3**	**11**	**12**
Siphonaptera		**1**	**1**	**1**
Strepsiptera		**1**	**1**	**1**
Thysanura		**1**	**3**	**3**
Total	**16**	**65**	**170**	**202**

10.2.2 Species Richness in Relation to Region

Insect species appear to differ greatly in extent of their distribution in the protectorate. Only one species; *Musca domestica* L. was widely distributed all over the studied zones. The high percentage (87.45%) of the insects were confined to only one specific zone in Zaranik area, among these insects, 156 species were restricted to Rest Building and its surrounding (Zone A); while 6 species were restricted to Flossyiat (Zone E). In addition, 4 and 3 species were confined to Fishermen settlements and adjacent places (Zone B), and Matli area, (Zone G). Moreover, 2 species were limited to Sandy bar (Zone C); with the same number of species confined to Islands (Zone F).

177 species were confined to only one zone, constituting 87.45% of the total fauna. While 15 species (7.43%) were confined to two zones; and only 9 species (4.46%) occupied three zones.

10.2.3 Species Richness in Relation to Habitat

The plant cover is very important for many groups of insects in Bardawil area, so it offers food or shelters for 69 species (34.16%). The species richer habitat is the sand dune habitat, inhabited with 61 species (30.2%), while the moorland habitat is populated with 25 species (12.38%). The salty marshes and shallow waters were habitats for only 7 species (3.47%). Furthermore litter, plant debris, dead trees, and organic matters were inhabited with 26 species (12.87%). Beside that, stores and indoor are occupied with one species for each.

10.2.4 Bionomics of Insect Species

Most obvious element of the insects is phytophagous species that include 80 species (39.6%); while 42 and 14 species of predators and parasitoids, respectively. The scavenger group of insects is represented by 35 species (17.33%); while omnivorous species include 16 species (7.92%). The dung feeder species are 8 (3.96%). The blood sucker group has the lowest percentage of species (1.98%).

10.2.5 Threatened species

El-Moursy *et al.* (2000) suggested that the species in Table 10.3 may represent the most threatened species. The population of these species is sensitive to habitat destruction or other environmental disturbance, which have not been determined until now. The factors that threaten these species need further investigation.

Table 10.5. **Threatened species and their habitat at Bardawil area (El-Moursy *et al.* 2000)**

Order/Family	Genus	Species	Habitat
Balttaria			
Blattidae	*Periplaneta*	*tartara* Saussure	In debris
Coleoptera			

Carabidae	*Cicindela*	*aulica* Dejean	Sandy shore
Carabidae	*Megacephala*	*euphratica* Lat.	Moorland
Carabidae	*Paussus*	*thomsoni* Reiche	Sand dune (under stones)
Carabidae	*Tachys*	*scutellaris agyptiacus* Sch. & Koch	Moorland
Carabidae	*Trichis*	*maculatus* Klug	Moorland
Cerambycidae	*Phytoecia*	sp.	On plants
Dytiscidae	*Eretes*	*sticticus* L.	Salty marshes
Elateridae	*Isidus*	*letourneuxi* Pic	Under litters
Lathrididae	*Melanophthalma*	*distinguenda* Comolli	In debris or under bark &stones stones
Scarabaeidae	*Trox*	*squalidus* (Olivier)	Dung
Diptera			
Bombyliidae	*Exhyalanthrax*	sp.	Sand dune
Bombyliidae	*Petrorossia*	sp.	Sand dune
Bombyliidae	*Spogostylum*	*candidum* (Sack)	Sand dune
Tabanidae	*Tabanus*	*albifacies* Loew	Sand dune
Therevidae	*Neothereva*	*angustifrons* Krob.	On plants
Heteroptera			
Pentatomidae	*Acrosternum*	*millieri* (Mulsant & Rey)	On plants
Mantodea			
Mantidae	*Iris*	*orlatoria* (L.)	On plants
Odonata			
Coenagriidae	*Ischnura*	*senegalensis* (R.)	Salty marshes
Libellulidae	*Crocothemis*	*erythraea* Brulle	Salty marshes
Strepsiptera			
Mengenillidae	*Mengenilla*	sp.	On plants

10.2.6 Management Policy for Threatened Species

Management for conservation of biological diversity can take two general approaches;

1- One is the species management approach. This approach needs more volunteers to protect all listed threatened species, and it will be difficult if this list is very long.

2- The second approach to manage biodiversity is the habitat conservation, or ecosystem-based approach. This approach assumes that maintaining a wide variety of habitat conditions in appropriate landscape patterns will help to support the greatest number of insect species.

El-Moursy *et al.* (2000) preferred the second approach "Habitat Conservation Plans", and they put some priorities to maximize conservation:

1- Preventing collection of threatened species.

2- Control collection of other non-threatened species.

3- Protect the habitat against fragmentation. Roads, trails, and powerline or pipeline corridors that can break up large, contiguous habitat into more fragmented mosaic type of habitat patch sizes. Local biodiversity is significantly affected as habitat patch size is reduced. Small, isolated patches support smaller populations of species, making them more

susceptible to local extinction. Patch size is particularly critical to the so-called "area-sensitive" species; organisms requiring large patches of contiguous habitat.

4- Control the activities of Salt Company, especially the construction of salt pans that lead to more concentration of the salts. Salts affect the soil characters; consequently the biodiversity related to the soil is affected too.

5- Prevent introducing of non-indigenous species, to protect the local indigenous ones against competition with the invasives.

6- Some sites containing considerable plant covers and representing different habitats should be protected and fenced against grazing and other human activities. These sites are very essential breeding, sheltering and conservatory places for many groups of insects.

7- Don't remove the debris, tree litter and logs, and large stones, because these microhabitats harbor many species.

10.2.7 Monitoring

Monitoring species serves to determine the status of the populations. These types of survey are very important because it makes it possible to follow the statistical trends of populations during the course of several years (time series).

Given the great diversity of species, monitoring of all the biological components of managed ecosystems is impossible. There is no easy method to decide how management can consider the full complement of species that occur in ecosystems. Based solely on pragmatic considerations, management of biological systems may be simplified and made more cost-effective by considering only a small group of indicator species. The concept of an indicator species envisages a species that is highly associated with a specific habitat type and can be monitored to determine the possible reaction of the species to changes in this habitat type the implicit assumption in the use of indicator species is that they provide a reliable assessment of habitat quality, and that if the habitat is maintained for the indicator, conditions will be suitable for other species. Conceptually, we would expect species with narrower habitat ranges to be more sensitive to habitat changes and therefore to make better indicator species. The biology of the indicator species must be known in detail and sources of subjectivity when selecting, monitoring and interpreting indicator species identified.

Indicator species

El-Moursy *et al.* (2000) suggested 6 species that can be used as indicators for habitat conservation:

- Indicator for Sand Dune habitat: *Thermophilum sexmaculatum pharaonum* (Coleoptera, Carabidae) *Neoclisis lineata* (Neuroptera, Myrmelionidae)

- **Indicators for saltmarshes habitat:** *Cicindela litorea* (Coleoptera, Carabidae) *Scarites guineensis* (Coleoptera, Carabidae)

- **Indicator for Islets habitat:** *Syrdenus grayi* (Coleoptera, Carabidae)

- **Indicator for salt water:** *Sternolophus solieri* (Coleoptera, Hydrophilidae)

10.2.8. Recommendations

El- Moursy *et al.* (2000), after their first preliminary investigation in this region during 2000, they suggested the following recommendations:

- More collecting in the area is required to survey the fauna periodically as a whole. The species listed in this work may represent an estimated 60% of the total insect fauna of Bardawil area and Zaranik Protectorate. This estimation is based on the total species found in similar adjacent regions and probably to be found in Zaranik with further collecting. Very important groups like bird lice and sucking lice, which are ectoparasites on birds and mammals, need to be collected and monitored, this seems like a gap in the 2000 survey.

- The monitoring time must be conducted for 2 years at least to get more reliable information for conservation management.

- Research must be continued to reveal the key factors, which affect biodiversity in general and the threatened species in particular.

- The Protectorate contains some medically important insects "like mosquitoes, sand flies, and biting midges" which may transmit dangerous diseases to visitors or residents. So, it is recommended to provide means of medical protection to the people there.

- Insects play a very important role in the ecosystems within the protectorate (as pollinators for plants, as food for some migratory birds, as bioindicators for pollution, ...etc); consequently, detailed ecological studies are needed to reveal these roles in the future.

10.3. SUMMARY

55 spiders and scorpions, belonging to 3 orders were recorded in Bardawil area and Zaranik Protectorate during 2000. Spiders represented 89% of the total arachnids, followed by scorpions (6%) and pseudoscorpions (5%). Spiders of 20 families were collected from 13 sampled sites , the dominant families were Liocranidae, Salticidae, Lycosidae and Gnaphosidae. Collecting sites near the Visitors Centre of the protected area were the first sites in number of spider taxa and individuals.

About false scorpions, nine specimens of family *Olpiidae* were collected in August, October and November, from under stones or wet algae remnants and pitfall traps. Three scorpion species of family Buthidae were recorded in

this preliminary survey. All specimens were found under stones or in big pitfall traps in August and October

About Insecta, El-Moursy *et al.* (2000) carried out four entomological expeditions to Bardawil area, between August and November 2000. 19 sites were surveyed, yielding a total of 853 specimens. 32.18 % of recorded species is accounted for only one insect order; Coleoptera or beetles (65 species), although 15 other orders are represented in the fauna. Diptera or flies (15.35%), Lepidoptera (13.86%), Hymenoptera (Ants, wasps and bees) (9.41%), Heteroptera or bugs (7.92%), Orthoptera or crickets, grasshoppers and locusts (5.94%), Neuroptera or ant-lions and aphid-lions (5.45%). The other insect orders made up 7.92% of all recorded orders.

Within 202 species, there are 29 species (14.36%) very common, 7 species (3.47%) are very rare, 39 species (19.31%) are common, 67 species (33.17%) are moderately common, and 60 are rare species (29.70%).

The plant cover in Bardawil area is very important for many groups of insects, so it provides food or shelters for 69 species (34.16%). The species-richer habitat is the sand dune habitat, which was inhabited with 61 species (30.2%), while the moorland habitat is populated with 25 species (12.38%). The salty marshes and shallow waters were occupied with only 7 species (3.47%). Furthermore the litters, plant debris, dead trees, and organic matters were inhabited with 26 species (12.87%).

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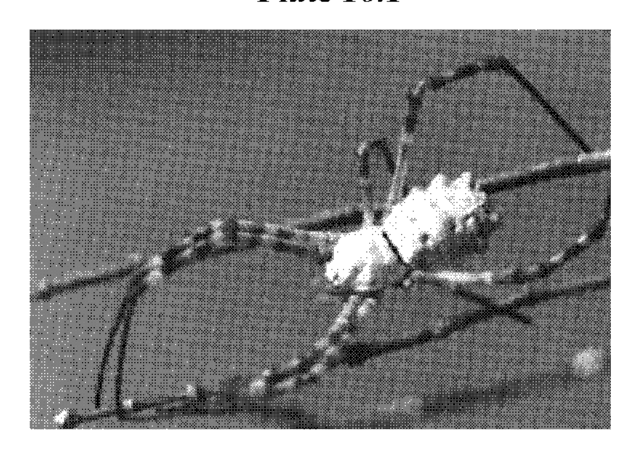
10.5 PLATES OF Arachnida (10.1 – 10.3)
(after El-Hennawy 2000)

Plate 10.1
Argiope lobata ♀
Stegodyphus lineatus ♂

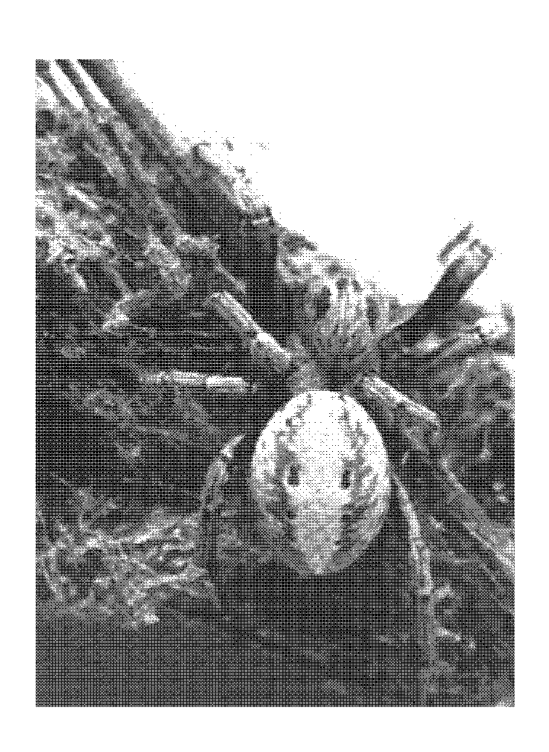
Plate 10.2
Pterotricha sp. ♀.
Thomisus spinifer ♀

Plate 10.3
Mogrus sp. ♂
Plexippus paykulli ♂

Plate 10.1

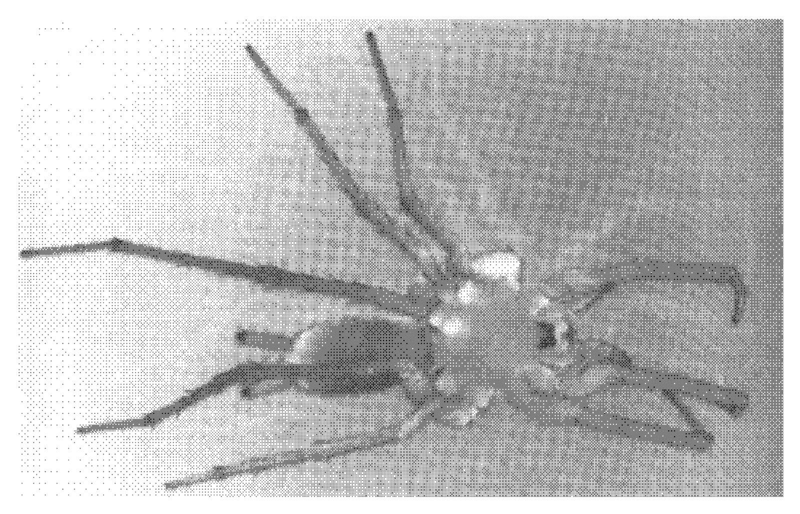


Argiope lobata **♀**

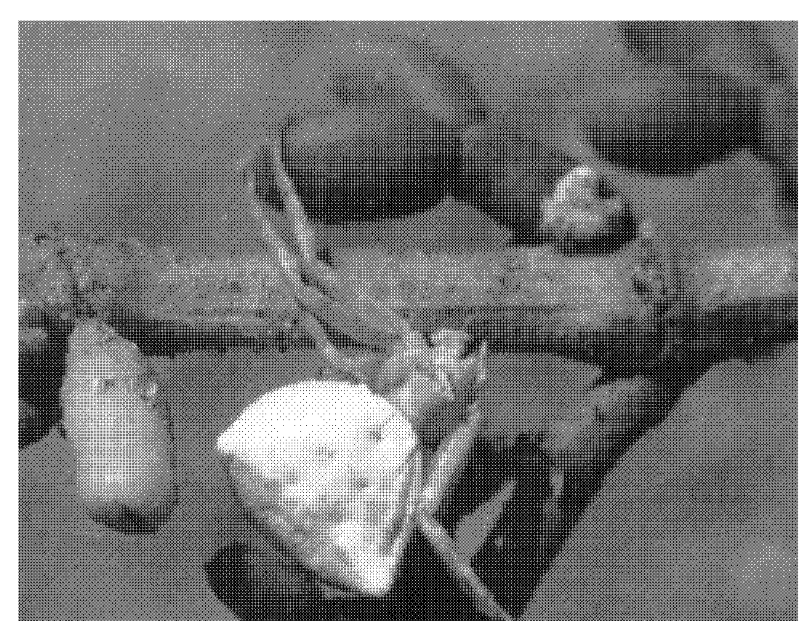


Stegodyphus lineatus **♂**

Plate 10.2

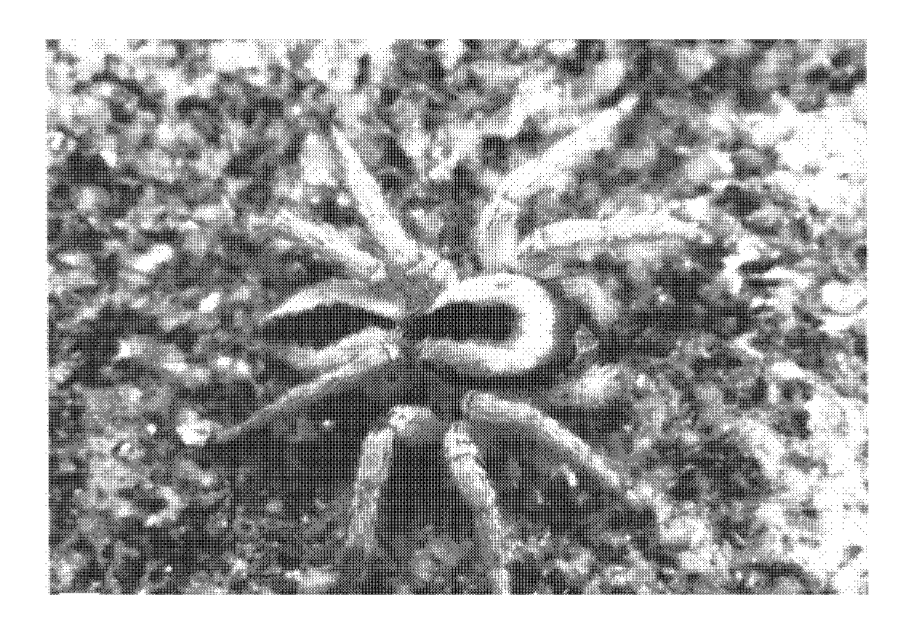


Pterotricha sp. ♀

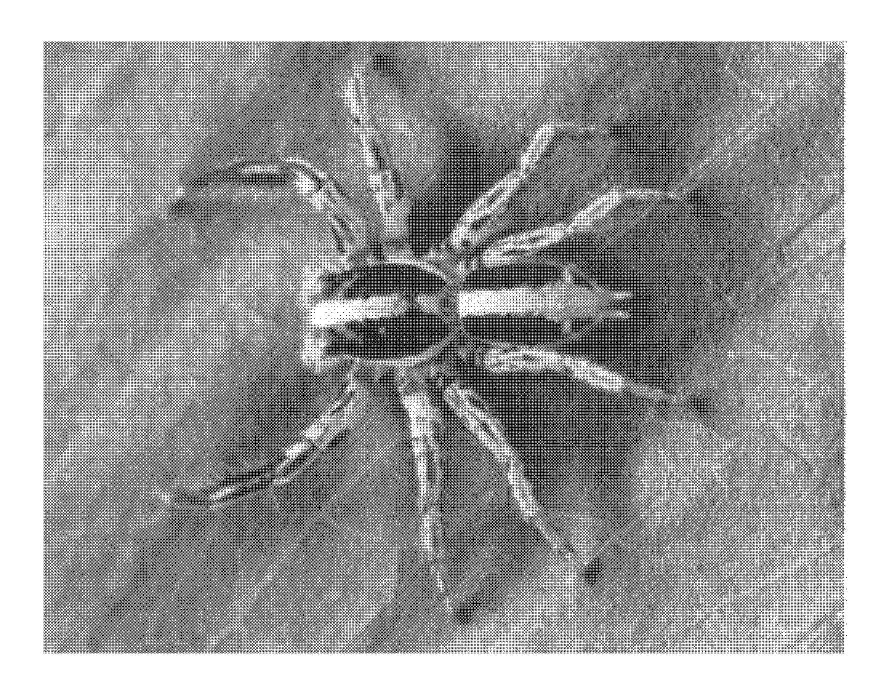


Thomisus spinifer ♀

Plate 10.3



Mogrus sp. ♂



Plexippus paykulli ♂

Chapter 11
Herpetofauna

Sinai is the richest part of Egypt herpetologically (Flower 1933, Saleh 1997), comprising 67 out of a total of 110 reptilian species. This is in part due to its exceptional geographic position and its varied topography and climatic condition.

Early zoological exploration in the Sinai peninsula began with several expeditions of Edward Rüppell in 1817. The last excursion by Rüppell was in 1830, whose collections seem to have included a very few specimens of reptiles. Heyden (1827) reported on Rüppell 's African collection including a description of *Agama sinaita*. Rüppell (1845) issued a catalogue of herpetofauna after which many additions to the herpetofauna of Sinai had been made. Hart (1891) recorded some herpetofaunal species from Sinai, Arabia and Wadi Araba. Anderson (1898) paid a special attention and spared no expense in suitably illustrating his book "Zoology of Egypt" discussing and analyzing the structure, morphology, taxonomy and some ecological aspects of the Egyptian herpetofauna covering Sinai. Barbour (1914) recorded 18 reptilian species from the Southern Sinai. Flower (1933) listed 42 herpetofaunal species from Egypt and Sinai. Out of these, two species, *Testudo kleinmanni* Lortet and *Hemidactylns turcicus* Linnaeus were reported from El-Arish area and one species *Agama pallida* Reuss from Wadi El-Arish. Haas (1943) recorded some reptilian species from Sinai. He (1951) discussed and described the status of *Mesalina olivieri* (Audouin) in Sinai and Palestine as a distinct form. Schmidt & Marx (1956) listed 50 discrete taxa of the herpetofaunal species known from Sinai comprising three species, *Bufo viridis, Testudo kleinmanni,* and *Scincus scincus* from El-Arish area. Hoofien (1957) added the lacertid lizard, *Mesalina brevirostris* (Blanford) to the fauna of Sinai. He (1972) submitted a taxonomic list of 91 reptile species from Israel and its administered areas including the occupied Sinai during such a time.

Out of a total of 23 species recorded from Sinai, Marx (1968) reported only one species, *Tropiocolotes tripolitanus* from El-Arish. Werner (1973)

mapped 48 species of amphibians and reptiles from Sinai. Of the collection, 14 species were recorded from El-Arish area. In 1982, Werner listed 55 herpetofaunal species from Sinai. He pointed out that of all the reptiles of Sinai, those inhabiting the northern sand dunes constitute the most clearly defined community; many of these species are strict psammophiles not occurring in adjacent soils. Zinner (1974) studied the distribution and population dynamics of snakes in the Negev and Sinai recording *Walterinnesia aegyptia* in several locations of the Northern and central Sinai. Ibrahim (1990) carried out herpetofaunal survey of El-Arish area including El-Arish City. His study yielded one toad, two marine turtles, and 18 terrestrial reptilian species. He briefly described the habitat structure and seasonal distribution of the species. Baha El Din (1992) gave notes on some herpetofaunal species already found in Sinai, and he (1997) added *Acanthodactylus longipes to* the herpetofauna of Sinai. Ibrahim (1996) studied the community of reptiles in sand dunes in AJ-Arish area. A total of 12 species of lizards and snakes were recorded as follows: *Acanthodactylus scutellatus, Mesalina olivieri, Trapelus flavimaculata, Stenodactyluspetrii, Sphenops sepsoides, Cerastes vipera, Chamaeleo chamaeleon musae, Varanus griseus, Scincus scincits, Chalcides ocellatus, Spalerosophis diadema, and Lytorhynchus diadema*.

In the northern plain of Sinai, *Artemisia monosperma* is a dominant plant species (Zahran & Willis 1992). In EL-Arish area, *A. monosperma* shows a very high constancy (based on the relative abundance and/or frequency of occurrence) when compared to some other plant species such as *Convolvulus lanatus, Echinops galalensis, Heliotropium digynum, Hyoscyamus* sp., *Panicum turgidum, Moltkiopsis ciliata* and *Pancratium* sp. (Ibrahim 1990).

The main herpetofauna habitats in Bardawil area and Zaranik protected area are undulating sand and stable sand dunes (occupying the largest area), salt marshes, artificial lagoons, and marine water of the Mediterranean. There are confined areas of coarse condensed sand, but some 20 km inland, ample gravel plain occurs. Zaranik area seems similar to El-Arish area, in terms of sand dune habitats, climate and its vicinity to the Mediterranean. However, vegetation is generally sparse, with the main dominant species on sandy areas, *Stipagrostis scoparia, Panicum turgidum, Artemisia monosperma, Retama raetam, and Thymelea hirsuta*. The dominant species in salt marshes are *Halocnemum strobilaceum and Salicornia europaea. Zygophyllum aegyptium* shrubs are found on higher and less saline ground.

Some herpetological studies have been carried out in El-Arish and Zaranik protected area (Baha El Din 1992, 1996). Ibrahim (1999) presented a method for tracking the desert monitor, *Varanus griseus* in Zaranik, and studied the ecology of that monitor using the radiotelemetry technique for the first time in Egypt.

Family	Latin name	English name	Arabic name

GEKKONIDAE	***Hemidactylus turcicus***	**Turkish Gecko**	برص منزلى
	Ptyodactylus hasselquistii	**Fan-Footed gecko**	برص ابو كف
	Stenodactylus petrii	**Petrie's Gecko**	برص واسع العين
	Stenodactylus sthenodactylus	**Elegant Gecko**	برص واسع العين
AGAMIDAE	***Trapelus savignyi***	**Savigny's Agama**	قاضى الجبل
LACERTIDAE	***Acanthodactylus boskianus***	**Bosc's Fringe-toed Lizard**	سقنقر خشن
	Acanthodactylus longipes	**Saharan Fringe-toed Lizard**	سقنقر
	Acanthodactylus scutellatus	**Nidua Fringe-toed Lizard**	سقنقر الرمل الكبير
	Mesalina olivieri	**Olivier's Lizard**	سقنقر سينائي مخطط
SCINCIDAE	***Chalcides ocellatus***	**Ocellated Skink**	سحلية دفانة
	Scincus scincus	**Sandfish**	سقنقور
	Sphenops sepsoides	**Audouin's Skink**	سحلية نعامة
CHAMAELEONTIDAE	***Chamaeleo chamaeleon***	**Common Chameleon**	حرباء
VARANIDAE	***Varanus griseus***	**Desert Monitor**	ورل صحراوى
VIPERIDAE	***Cerastes vipera***	**Sand Viper**	حية قرعاء
COLUBRIDAE	***Lytorhynchus diadema***	**Sand Snake**	بسباس
	Psammophis schokari	**Schokari Sand Snake**	هرسين
	Spalerosophis diadema	**Clifford's Snake**	أرقم احمر
	Malpolon moilensis	**Moila snake**	أبو العيون
TESTUDONIDAE	***Testudo kleinmanni***	**Egyptian Tortoise**	سلحفاة مصرية
CHELONIDAE	***Caretta caretta***	**Loggerhead Turtle**	ترسة
	Chelonia mydas	**Green Turtle**	سلحفاة خضراء
DERMOCHELYIDAE	***Dermochelys coriacea***	**Leatherback Turtle**	سلحفاة جلدية الظهر
11	**23**		

Table 11.1. **Reptiles recorded from Bardawil and Zaranik Protected Area**

11.1 SPECIES COMPOSITION

Ibrahim (2000) studied the amphibians and reptiles in Bardawil area through 9 stations as follows:

Station 1: on and around Zaranik protectorate buildings.
Station 2: Fluseyyat island
Station 3: Matli island
Station 4: Khowaynat
Station 5: Abu Al-Hussein (Village and sand dune).
Station 6: Mazar (Village and sand dunes)
Station 7: Sebeeka (Salt factory and surrounding buildings)
Station 8: North eastern shore site.
Station 9: Mahasna island (Abu Meheesen)

These stations covered almost all the available habitats in Bardawil and Zaranik protected area, including stable sand dunes, hard soil areas, houses and ruins, and marine habitat.

Ibrahim (2000) recorded 23 species of reptiles (14 lizard species including 7 families, and 11 genera; 4 snakes, including 2 families and 5 genera; one tortoise, and 3 sea turtles including 3 families and 3 genera) (Table 11.1). No amphibian was recorded, although the green toad, *Bufo viridis* could occur in the green patches of the protected area with available fresh water.

11.2 SPECIES ACCOUNT

Class: Reptilia

Order: Squamata

Suborder: Sauria

Family: Gekkonidae

1- *Hemidactylus turcicus* (Linnaeus, 1758).

Common name: Turkish or Warty or Mediterranean Gecko, برص منزلى

World distribution: North Africa.

National distribution: Suitable localities throughout Egypt and Sinai.

Bardawil observation sites: This gecko was recorded from three localities with buildings such as the administration or visitors building, old railway station ruins in Mazar, and in salt factory buildings at Sebeeka.

Habitat: It is mostly found on rocks and it also frequents walls of old buildings.

Ecology: It occurs mostly in contact with human settlement. In Egypt, it is the most common house gecko. For more details see Saber (1999).

Status: Lower Risk (Least concern).

2- *Ptyodactylus hasselquistii hasselquistii* (Donndroff, 1798)

Common name: Fan-Footed gecko, (*Bors or Braiss*) برص ابو كف

World distribution: Northeastern Africa, Sinai and the Arabian Peninsula

National distribution: Sothern /Sinai and Upper Egypt

Bardawil observation sites: The existence of this gecko was restricted to the salt factory and adjacent railway station old buildings.

Ecology:A diurnal, rock dwelling species, usually numerous on rocky sides and under overhanging ledges of wadis and on walls of old buildings. It seldom comes to the ground, feeding exclusively on insects and other arthropods that happen to be on these rocky surfaces. Individuals appear to be territorial defending exclusive feeding areas.

Status: Lower Risk (least concern).

3- *Stenodactylus petrii*, (Anderson, 1896*)*

Common name: Petrie's Gecko, برص واسع العين

World distribution: Egypt, westward to Libya, Tunisia and Algeria and eastward to Sinai and Israel.

National distribution: Sandy areas in the Western Desert, the eastern fringes of the Nile Delta, and northern Sinai.

Bardawil observation sites: It is a nocturnal gecko found in all soft sand dune in the protectorate and around the visitor and administration buildings.

Ecology: Restricted to sandy desert, where it can be found among dunes and phytogenic mounds. Strictly nocturnal and can often be found active during very cold desert nights. It feeds on nocturnal, surface-active insects and other arthropods of the desert.

Status: Lower Risk (near threatened)

4- *Stenodactylus sthenodactylus sthenodactylus* (Lichtenstein, 1823)

Common name: Elegant Gecko برص واسع العين

World distribution: North Africa south to Senegal, northern Nigeria and Eritrea and east to Israel and Jordan.

National distribution: Widespread in desert habitats throughout the Western and Eastern Deserts and Sinai and desert margins of the Nile Valley.

Bardawil observation sites: It is found only in Abul Hussein during day under a hard cover of dry waste products of sheep and goats.

Ecology: A ground-dwelling gecko, widespread but generally in small numbers. Has been collected in a variety of desert habitats including among vegetation between sand dunes, under stones in gravel or rocky desert, and far from cultivated fields of the Nile Valley.

Status: Lower Risk (near threatened).

FAMILY: Agamidae

5- *Trapelus* (*savignyi*) flavimaculatus Rüppell, 1835

Common name: Savingy's agama, قاضى الجبل

World distribution: Eastern Egypt to Israel and Arabia.

National distribution: Northern part of the Eastern Desert and Northern Sinai.

Bardawil observation sites: This lizard was frequently observed in Matli island. It was also found in sandy area around the administration buildings. This is the only agamid recorded in the area. However, Varty & Baha El Din (1991) found a road- killed juvenile individual, *Uromastix aegyptius* (Dabb) in the southern boundary of the protected area. This species is known to occur in the gravel and hard soil, and rocky areas in the northern and southern Sinai.

Ecology: A diurnal species inhabiting lowland desert, particularly sandy areas. During extremely hot weather it may climb on desert bushes.

Status: Lower Risk

FAMILY: Lacertidae

6- *Acanthodactylus boskianus asper* (Daudin, 1802).

Common name: Bosc's Lizard; سقنقر خشن

World distribution: Widespread throughout North Africa and southwestern Asia.

National distribution: Common throughout desert areas and margins of Nile Valley and Delta.

Bardawil observation sites: It was only observed in the Mahasna island in Lake Bardaweel included in the protected area. It is said to have been observed in a habitat of hard ground, very close to the northern sea shore of the protectorate (Omar Attum, pers. comm.). An extensive field work has been done in Zaranik sea shore, but no lizard was observed

Habitat: Sparsely vegetated areas with gravel and stones, but less on sand.

Ecology: A diurnal species, feeds on a variety of food items.

Status: Lower Risk (Least concern).

7- *Acanthodactylus longipes* Boulenger, 1918

Common name: Saharan fringe-toed Lizard, سقنقر

World distribution: Southeastern Morocco, the Algerian Sahara, Western Mauritanin, Libya, Egypt, Mali, Chad and Niger.

National distribution: Baha El Din (1994), based on Egyptian material in the British Museum (Natural History) reported this species from northern Sinai, near Suez, Giza, Faiyum, Wadi El Natrun and Siwa Oasis. Specimens were collected by the author in El Arish and Bir El Abd areas in northern Sinai; Abu Rawash, Wadi El Natrun, Wadi El Raiyan, Sitra and Siwa oases, and Hatiyat Abdel Nabi in the Qattara Depression.

Bardawil observation sites: This lizard is a common diurnal species, mainly found in soft sandy soil, coexisting with the most analogous species, *A. scutellatus.*

Ecology: In northern Sinai where the species is found in sympatry with *A. scutellatus, A. longipes* is reported to occupy soft sand and dunes, while *A. scutellatus* prefers areas of compacted sand and gravel plains (Baha El Din, 1994). Such habitat differentiation was not observed in Wadi El Raiyan where the two species inhabit areas of sand dunes and appear to share identical habitats. It is more likely that some type differentiation in the mode of resource utilization is the underlying mechanism that permits the coexistence of these two closely related species.

Status: Lower Risk (least concern).

8- *Acanthodactylus scutellatus scutellatus* (Audouin, 1829).

Common name: Nidua Lizard; سقنقر الرمل الكبير

World distribution: North Africa to southwestern Asia.

National distribution: Western, Eastern and Sinai deserts.

Bardawil observation sites: It is very common, observed everywhere in the protectorate sandy soils, as well as gravel and stony habitats in the Fluseyyat island in particular.

Habitat: Open sandy desert.

Ecology: A diurnal species, feeds on small insects (Saber 1989).

Status: Lower Risk (Least concern)

9- *Mesalina olivieri* (Audouin, 1829).

Common name: Olivier's Lizard, سقنقر سينائى مخطط

World distribution: North Africa to southwestern Asia

National distribution: Probably widespread throughout North and south Sinai. Gobashi *et al.* (1990) reported this species from El Arish. Specimens were collected by the author in Ras Mohamad, Elwat El Agramiya (Saint Katherin's area), Bir El Abd and El Arish.

Bardawil observation sites: It is a common species, observed in almost all sand dunes, in sympatry with the two previously mentioned lacertids.

Ecology: Appears to prefer sandy areas with light vegetation cover, from sea level to the high mountain wadis of southern Sinai

Status: Lower Risk (least concern).

FAMILY: Scincidae

10- *Chalcides ocellatus ocellatus* (Forskal, 1775).

Common name: Eyed Skink; Ocellated Skink; سحلية دفانة

World distribution: North Africa to southeastern Europe and southwestern Asia.

National distribution: Throughout desert areas, Mediterranean coastal desert of Egypt and Sinai.

Badawil observation sites: It was captured from sand soil with dense vegetation, under hard cover, and also around the protectorate buildings.

Habitat: Sandy desert, it may inhabit also banks of irrigation canals.

Ecology: It is crepuscular, semifossorial, living under sand or dead vegetation.

Status: Lower Risk (Least concern).

11- *Scincus scincus* (Linnaeus 1758),

Common name: Sandfish; ***Saqanqour*** سقنقور

World distribution: North eastern Africa

National distribution: Mediterranean Coastal Desert of Egypt and Sinai and sandy areas of the Western Desert and the northern part of the Eastern Desert.

Bardawil observation sites: is a common fossorial species, existing in all sandy soils, especially the soft ones, in sympatry with other skink such as *Sphenops sepsoides.*

Ecology: Restricted to sandy desert areas where it lives mostly under the sand but surfaces occasionally to run on the sand surface at night.

Status: Low Risk (least concern).

12- *Sphenops sepsoides* (Audouin, 1827)

Common name: Audoin's Sand Skink سحلية نعامة

World distribution: North Africa to southwestern Asia.

National distribution: Western, Eastern and Sinai Deserts.

Bardawil observation sites: It is the most common skink observed on the ground. Tracks of this skink were observed everywhere, on the sand soil and around buildings.

Ecology: A sand-dwelling, fossil species, found in a wide variety of habitats, ranging from sandy depressions of the Western Desert, to sandy spots in rocky wadis of the Eastern Desert and Sinai. It sand swims immediately beneath the sand surface, forming a characteristic winding track. It feeds on fossorial insects and other invertebrates such as pseudoscorpoins. It appears to be nocturnal (Werner 1968)

Status: Lower Risk (least concern).

FAMILY: Chamaeleontidae

13- *Chamaeleo chamaeleon chamaeleon* (Linnaeus, 1758).

Common name: Common Chamaeleon, European Chamaeleon, حرباء

World distribution: South Europe, North Africa, and southwest Asia.

National distribution: Western Mediterranean coastal desert, south to Moghra and Wadi El-Natrun and northern part of the Eastern Desert.

Bardawil observation sites: The chameleon was observed in four different sites, on the ground and on bushes during day. At night, it was observed sleeping on bushes.

Habitat: Vegetated desert area with bushes or trees.

Ecology: Arboreal species found on trees and bushes, when food becomes scarce they move away, even on the ground.

Status: Lower Risk (Least concern).

FAMILY: Varanidae

14-*Varanus griseus griseus* (Daudin, 1803),

Common name: Desert Monitor,Grey Monitor; ***Waral Saharawi*** ورل صحراوى

World distribution: North Africa and southwest Asia.

National distribution: Sandy areas throughout the Western and Eastern Deserts and northern Sinai.

Bardawil observation sites: This is the largest lizard in the Bardawil area. It is recorded in all sand dunes in Northern Sinai. In Zaranik, it was recorded in all stations, individual tracks were observed in front of one of the visitor building for two days.

Ecology: The Desert Monitor is common in desert and scrub country throughout Egypt. In its desert habitats, this large lizard is the diurnal counterpart of the mammalian nocturnal predator such as desert foxes *(Vulpes zerda* and *Vulpes rueppelli)* and the wild cat *(Felis libyca).* Favored food includes lizards, snakes and rodents. Individuals appear to cover very large areas when searching for food.

Status: Low Risk (least concern).

II-SNAKES

FAMILY: Viperidae

15-*Cerastes vipera* (Linnaeus, 1758)

Common name: Lesser Cerastes Viper; ***Haiya Qarah*** حية قرعاء

World distribution: North Africa.

National distribution: Sandy areas in the Mediterranean coastal desert, Western Desert, Northern part of the Eastern Desert and Sinai.

Bardawil observation sites: It is the only venomous viper recorded in Zaranik. It is confined to the sand dune biotopes. It is a nocturnal species was frequently captured from the loose sand in the top of the dunes. In El- Arish area, it reached its highest activity in September (Ghobashi *et al.* 1990).

Ecology: Inhabits sandy desert, particularly sand dune areas. It is often confused with hornless individuals of *Cerastes cerastes* and references to *C. vipera* in rocky deserts is probably of hornless *C. cerastes*. It appears to feed mostly on lizards, rodents and possibly birds. The stomach of a specimen collected in Wadi El Raiyan, Western Desert, had a Chiffchaff *Phylloscopus collybita*.

Status: Low Risk (least concern).

FAMILY: Colubridae

16- *Lytorhynchus diadema* (Dumeril, Bibron & Dumeril,1854)

Common name: Diademed Sand-Snake; *Bisbas* بسباس

World distribution: North Africa and southwest Asia.

National distribution: Sandy desert areas throughout Western and Eastern and Sinai Deserts.

Bardawil observation sites: A most common sand snake in Bardawil area. The tracks of that snake were observed in all sand dunes.

Ecology: A sand snake, inhabiting areas of loose sand and is specially adapted to a semi-inssorial life. It is essentially nocturnal but may become crepuscular in colder weather. It appears to feed mostly on insects and small lizards

Status: Low Risk (least concern).

17- *Psammophis schokari schokari* (Forsskal, 1775)

Common name: Sand Snake, هرسين

World distribution: Extends from extreme western North Africa to Egypt, south to Chad, Ethiopia and Somalia, east across the Arabian Peninsula and southwest Asia to northwest India and north to central Asia.

National distribution: Throughout desert areas both west and east of the Nile Delta and Mediterranean Coastal Desert and Sinai.

Bardawil observation sites: Semi-poisonous, collected and released in three sites, around administration buildings of protected area, and in the two villages, Mazar and Abul Hussein.

Ecology: A desert species, inhabiting a wide variety of desert habitats. It is often found among branches of desert bushes, but is not quite arboreal. It feeds mostly on small birds, rodents and lizards. It appears to be diurnal.

Status: Low Risk (least concern).

18-*Spalerosophis diadema cliffordii* (Schlegel, 1837)

Common name: Clifford's Snake, ***Arqam Ahmar***, أرقم أحمر

World distribution: Extends from extreme western north Africa to Egypt, south to Chad, Ethiopia and Somalia, east across the Arabian Peninsula and southwest Asia to northwest India and north to central Asia.

National distribution: Throughout desert areas both west and east of the Nile Delta and Mediterranean Coastal Desert and Sinai.

Bardawil observation sites: Semi-poisonous; only one individual's track was observed close to the administration buildings.

Ecology: A desert species, inhabiting a wide variety of desert habitats. It is often found among branches of desert bushes, but is not quite arboreal. It feeds mostly on small birds, rodents and lizards. It appears to be diurnal

Status: Low Risk (least concern).

19-*Malpolon moilensis* (Reuss, 1834)

Common name: Moila snake, (***Abu El-Ayune***), أبو العيون

World distribution: North Africa from Algeria to Egypt, South to Sudan, east to Sinai, Jordan, Syria, Iraq, Iran and the Arbian Peninsula. Specimens have also been reported from Ghana (Gasperetti 1988).

National distribution: Mediterranean Coastal Desert of Egypt and Sinai, Western and Eastern Deserts and northern Sinai. Specimens were collected in Bahariya Oasis, Wadi El Raiyan in the Western Desert and Gabal El Maghara in northern Sinai (Ibrahim 2000).

Bardawil observation sites: It was recorded on a single occasion in the southern frontier of the protectorate (Varty & Baha El Din 1991). No tracks of this species was recorded elsewhere in this study.

Ecology: A diurnal snake, but becomes crepuscular in hotter weather. It inhabits vegetated sandy desert areas and appears to feed mostly on desert rodents and lizards

Status: Low Risk (least concern).

FAMILY: Testudonidae:

20-*Testudo kleinmanni* Lortet, 1883

Common name: Egyptian Tortoise, (*Sohlefa*), سلحفاة مصرية

World distribution: Northeastern Libya, eastward to Sinai and southern Israel

National distribution: Mediterranean coastal deserts of Egypt and Sinai. At the present time, it is extremely rare, possibly extinct in the Western Mediterranean Coastal Desert. Baha El Din (1992) mentions possible, yet unconfirmed reports from an area southwest of El Arish, northern Sinai and the Um El Rumiat Island in Lake Bardawil. One specimen was found in 1993 in an area near Bir El Abd, northern Sinai. One record of a specimen Near Bir Gindali in the hilly desert between Cairo and Suez (Marx 1968) is often considered an introduction (Buskirk 1985) or an error. Baha El Din (1992) reports the remains of a dead individual of this tortoise in the nest of a Brown-necked Raven in a tributary of Wadi Gindali not far from the locality recorded by Marx.

Bardawil observation sites: Only a few individuals were recorded in Abul Hussein, but no exact locality for that tortoise, or even a nest, was observed.

Ecology: Inhabits vegetated sandy desert of the Mediterranean coast both east and west of the Nile Delta, feeding mostly on desert vegetation. Very little is known about the ecology of this species in Egypt. Mating takes place in September and October (Flower 1933). Eggs are laid in June.
Status: Critically Endangered

FAMILY: Chelonidae

21- *Caretta caretta* (Linnaeus, 1758)

Common name: Loggerhead Turtle; ترسة

World distribution: African Mediterranean coasts, Indian and Atlantic Oceans.

National distribution: Mediterranean Sea near Baltim (Burullus)and Red Sea at Ras Muhammad and near the northern tip of Aqaba Gulf.

Bardawil observation sites: It is very common in the area, their nests comprising about 80% of turtles in the Mediterranean Sea (Saleh 1997).

Habitat: Wide migrations in oceans, but also entering river mouths and lagoons

Ecology: It is omnivorous turtle, feeds on sponges, jelly fish, molluscs, tunicates, crustaceans, fish and also sea weeds.

Status: Endangered.

22- *Chelonia mydas* (Linnaeus, 1758)

Common Name: ***Green Turle***; سلحفاة بحرية خضراء

World distribution: Tropical, subtropical and temperate seas, including all African coasts, Indian Pacific and Atlantic Oceans.

National distribution: Egyptian coastal waters including Mediterranean and Red Seas.

Ecology: Feeding areas are shallow coastal sites with extensive growths of algae and sea grasses. The main food of the Green Turtle is sea grasses and algae; although jellyfish, molluscs, crustaceans and sponges are occasionally eaten. They nest on gently slopping sandy beaches at a few sites throughout the world. They may disperse over great distances from breeding site to feeding areas.

Status: Endangered.

Remarks: The main threat to this and other marine turtles, are the human activities. Destruction of nesting grounds caused by different coastal developments, including land filling of shallow coastal areas adversely affect this species in Egypt. Water pollution with oil and other pollutants appears to have a significant negative impact on its populations worldwide (Saleh 1997). The population of the green turtle in the Atlantic Ocean, as well as most of the Indo-Pacific is assigned to subspecies *C. mydas mydas*, while *C. mydas agassizii* is recognized as the form that distributed in the eastern Pacific Ocean

FAMILY: Dermochelyidae

23- *Dermochelys coriacea* (Vandelli, 1761)

Common name: Leatherback Turtle, (*Tersa*) , سلحفاة جلدية الظهر

World distribution: A circumglobal wandering species (Groombridge, 1982). **National distribution:** There are records of Leatherback Turtles in Hurghada and the Sinai coasts of the Gulfs of Suez and Aqaba. Flower recorded one specimen in the Alexandria fish Market (Flower, 1933). Baha El Din (1992) reported three individuals found dead on the Mediterranean coast of Sinai between the years 1985 and 1991. No nesting records are known from Egyptian coasts.

Bardawil observation sites: The Leather-backed turtle, *Dermochelys coriacea* (Tersa) was recorded once in the protected area when an old carcass was found in 1985 (Baha El Din 1992).

Ecology: It is a cold water pelagic reptile venturing into warmer tropical waters only intermittently and primarily for the purpose of nesting. Feeds on jellyfish, including highly venomous species such as the Portuguese Man of War.

Status: Endangered.

Remarks: This is one of the largest of extant reptiles in the world. The largest specimen ever recorded was found dead on a beach in Wales. It measured 2565 mm curved carapace length, weighed 916 kg and had a foreflipper span of 277 cm (Eckert & Luginbuhl 1988).

The Indo-Pacific population has been given the subspecific status of *schlegeli,* while the Atlantic Ocean population was given the nominate subspecies, *coriacea* (Smith & Smith 1979, Gasperetti *et al.* 1993).

No turtles or even its tracks were observed in the Bardawil study.

11.3 DISTRIBUTION

The station 5 (Abul Hussein village) is the richest one in terms of species number. This village is inhabited by a few people. It is characterized by having different kinds of habitats such as stable sand dunes that encompass the psammophile species, hard soil areas, plus houses and a mosque. The area includes 12 reptile species that may reflect the variety of habitats. The surroundings of the visitor's buildings of the protectorate follow Abul Hussein station in terms of number of species (11 species). They have sand dunes plus buildings. Reptiles were distributed irregularly.

11.4 SPECIES DENSITY

Density of species was estimated for only the most common species that were easily captured and recaptured through a pit-fall traps system. These species are: *Acanthodactylus scutellatus and A. longipes.* The density of *A. scutellatus* was 2400 /km ^{2}, while the sympatric lizard *A. longipes* was 10607/ km^2. Although almost all sandy areas of Zaranik were swarming with tracks of

Sphenops sepsoides, a very little fell in the traps. Hence, the estimation of its density was difficult.

11.5 SPECIES STATUS

- Common species

The most common species are: *Acanthodactylus scutellatus, Acanthodactylus longipes, Mesalina olivieri,* and *Sphenops sepsoides,* all inhabiting sand dune and sandy areas.

- Rare species

The gecko, *Stenodactylus sthenodactylus* is the most rare species as only one individual was collected. The Fan-footed gecko, *P. hasselquistii* is the first record for the Northern Sinai. Its occurrence is restricted to the salt factory in Sebeeka area, about 600 m only from the protected area buildings. This species is suggested to have been transported through the establishment of the factory in 1986. This gecko moved to the old adjacent abandoned railway station buildings, and a single individual was recently observed in the protectorate visitor's center.

- Endangered species

The Egyptian tortoise is the most endangered species in the area, and the nests of that species have almost disappeared in the few past years. Also, *Caretta caretta,* the Loggerhead Turtle and *Chelonia mydas,* the Green Turtle are considered endangered species. Efforts currently aim at the conservation of these threatened species.

-Endemic species

No endemic species was recorded.

11.6 SUMMARY

23 species of reptiles were recorded in Bardawil area and Zaranik Protectorate (14 lizard species including 7 families, and 11 genera; 4 snakes, including 2 families and 5 genera; one tortoise, and 3 sea turtles including 3 families and 3 genera). No amphibian was recorded, although the green toad, *Bufo viridis* could occur in the green batches of the protected area with available fresh water.

The most common species *are Acanthodactylus scutellatus, Acanthodactylus longipes, Mesalina olivieri,* and *Sphenops sepsoides.* All of them inhabiting the sand dune and sandy areas.

The gecko, *Stenodactylus sthenodactylus* is the most rare species as only one individual was collected during a study in 2000. The Fan-footed gecko, *P. hasselquistii* is the first record for the Northern Sinai. Its occurrence is restricted to the salt factory in Sebeeka area, about 600 m only from the protected area

buildings. This species is suggested to have been transported through the establishment of the factory in 1986.

The Egyptian tortoise is the most endangered species in the area, and the nests of that species have almost been disappeared in the few past years. Also, *Caretta caretta*, the Loggerhead Turtle and *Chelonia mydas*, the Green Turtle, *Dermochelys coriacea*, Leatherback Turtle are considered endangered species. Efforts currently aim at conservation of these threatened species.

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11.8. PLATES OF REPTILES (11.1 – 11.9)

(after Website: www.gescities.com/herpetology_bg/contents.htm)

Plate 11.1
Hemidactylus turcicus
Ptyodactylus hasselquistii

Plate 11.2
Stenodactylus petrii
Stenodactylus sthenodactylus

Plate 11.3
Acanthodactylus boskianus
Acanthodactylus scutellatus

Plate 11.4
Chalcides ocellatus
Scincus scincus

Plate 11.5
Sphenops sepsoides
Chamaeleo chamaeleon

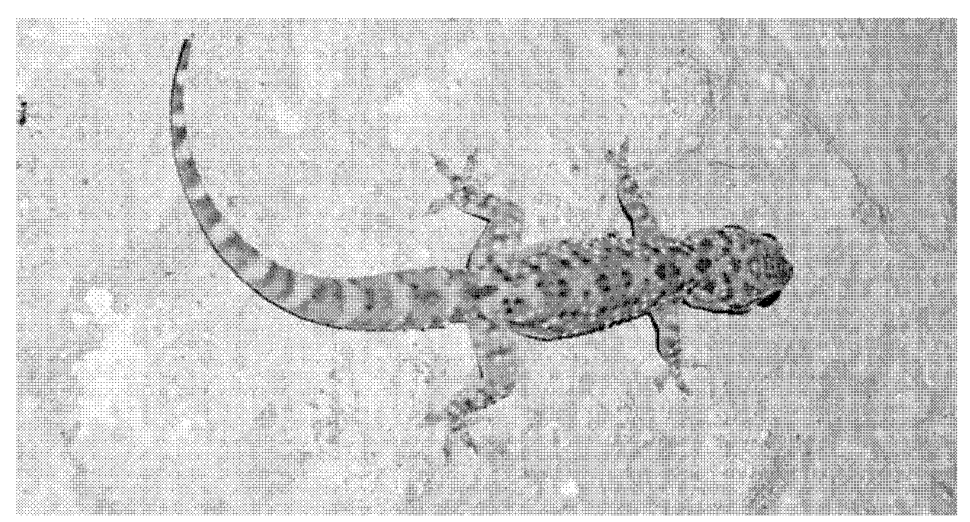
Plate 11.6
Varanus griseus
Lytorhynchus diadema

Plate 11.7
Psammophis sibilans
Spalerosophis diadema

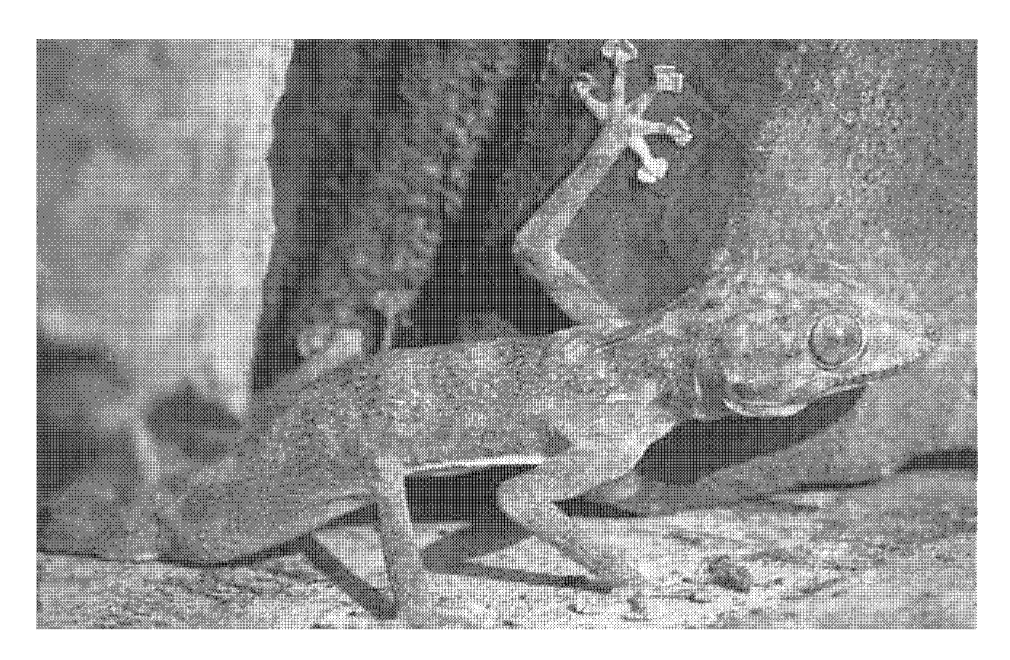
Plate 11.8
Chelonia mydas
Caretta caretta

Plate 11.9
Testudo kleinmanni

Plate 11.1

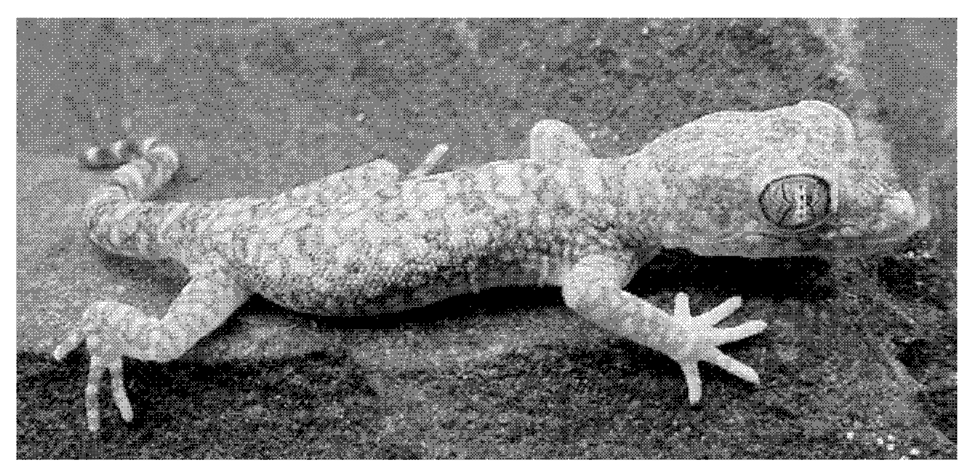


Hemidactylus turcicus turcicus برص منزلي

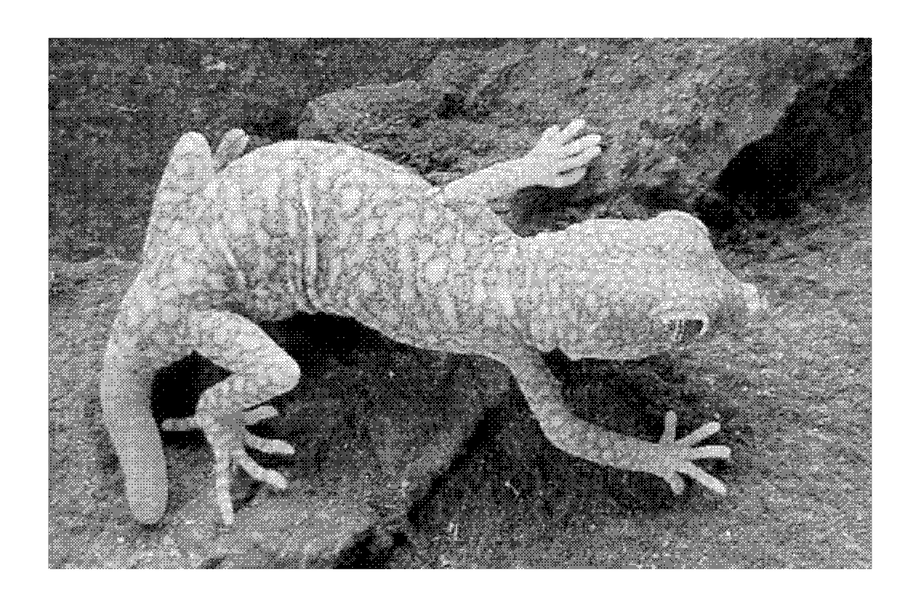


Ptyodactylus hasselquistii برص أبو كف

Plate 11.2

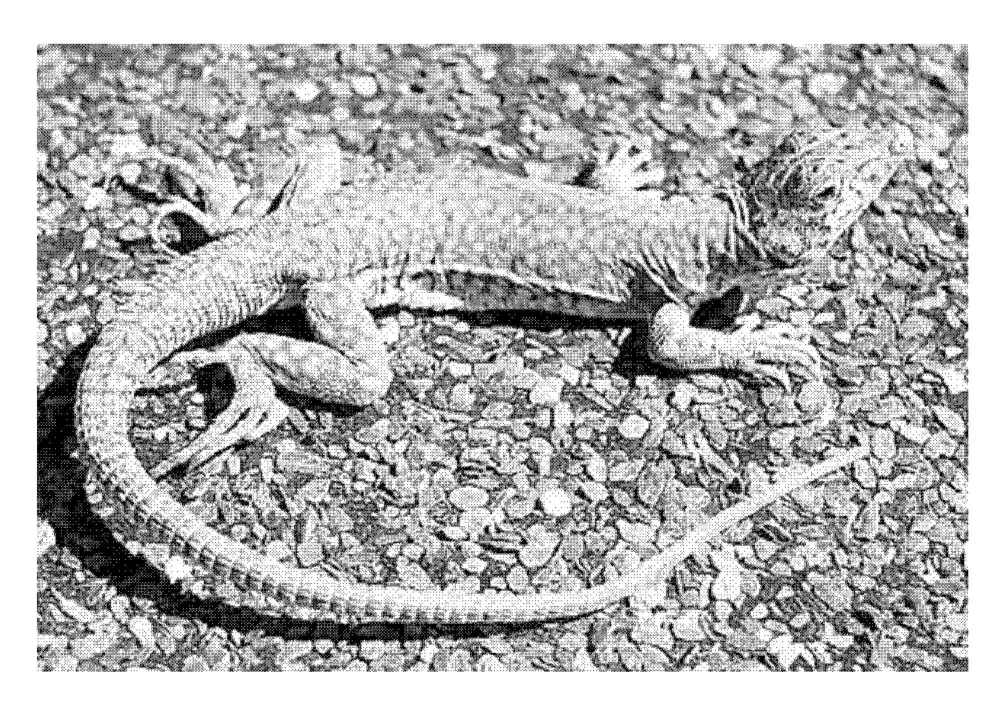


Stenodactylus petrii برص واسع العين

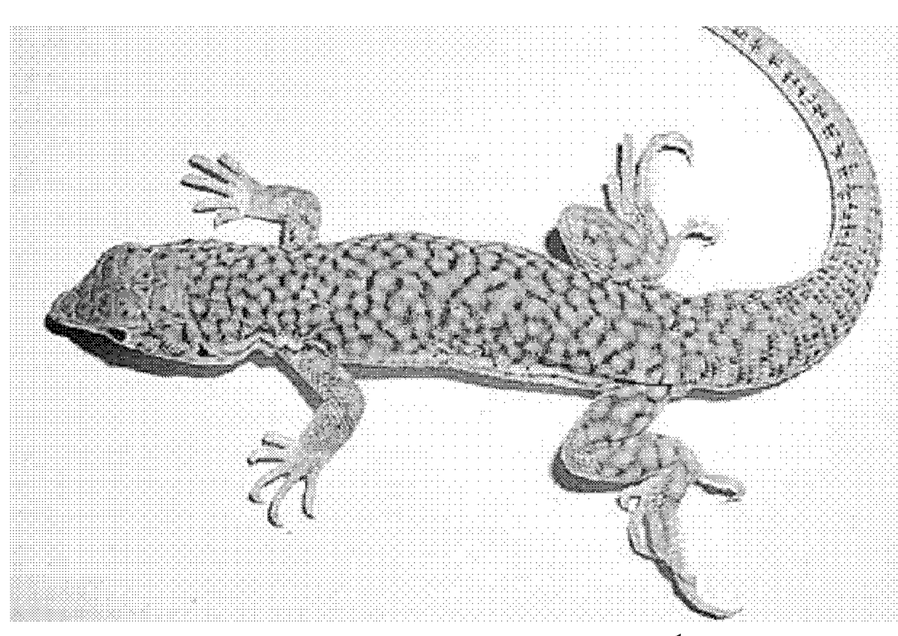


Stenodactylus sthenodactylus برص واسع العين

Plate 11.3



Acanthodactylus boskianus سقنقر خشن

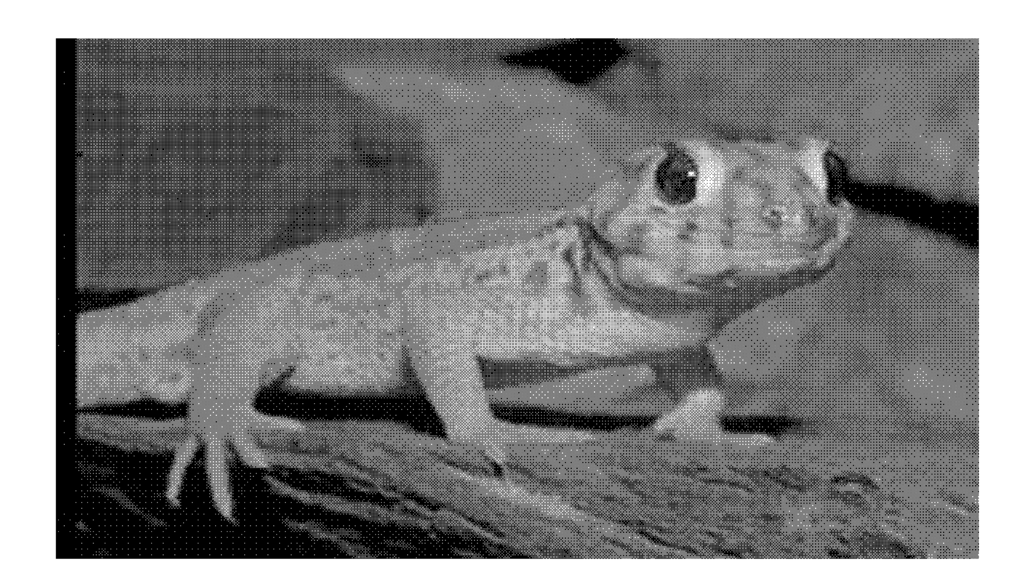


Acanthodactylus scutellatus سقنقر الرمل الكبير

Plate 11.4

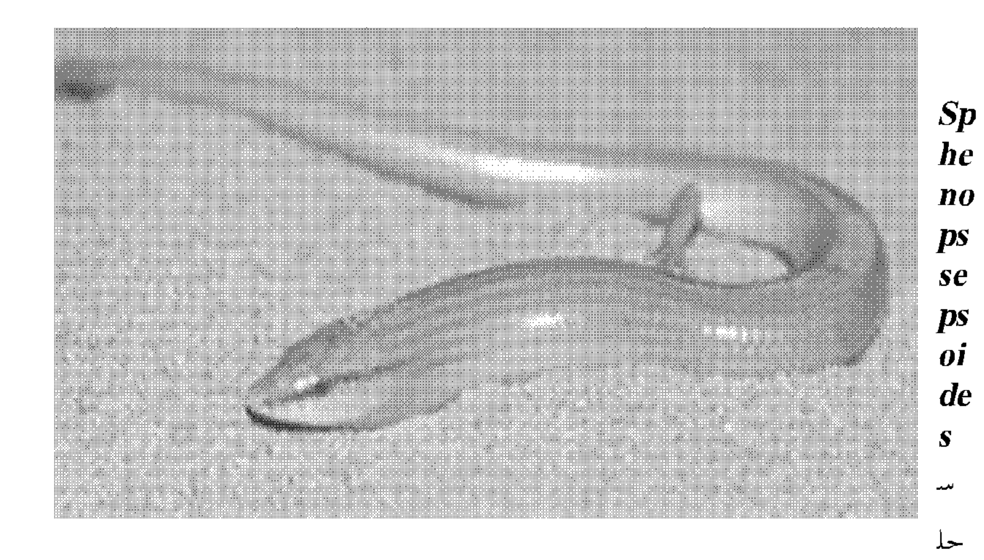


Chalcides ocellatus سحلية دفانة

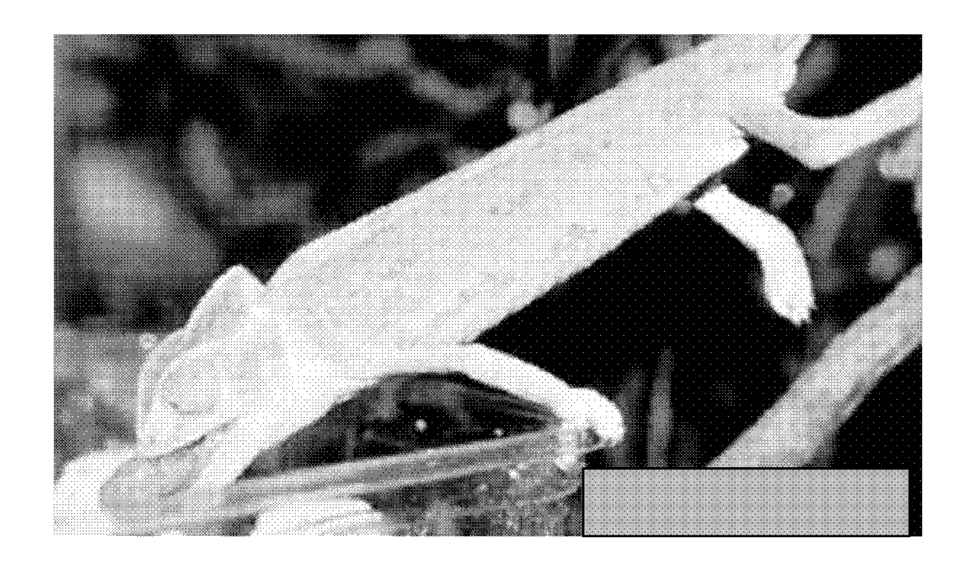


Scincus scincus سقنقور

Plate 11.5

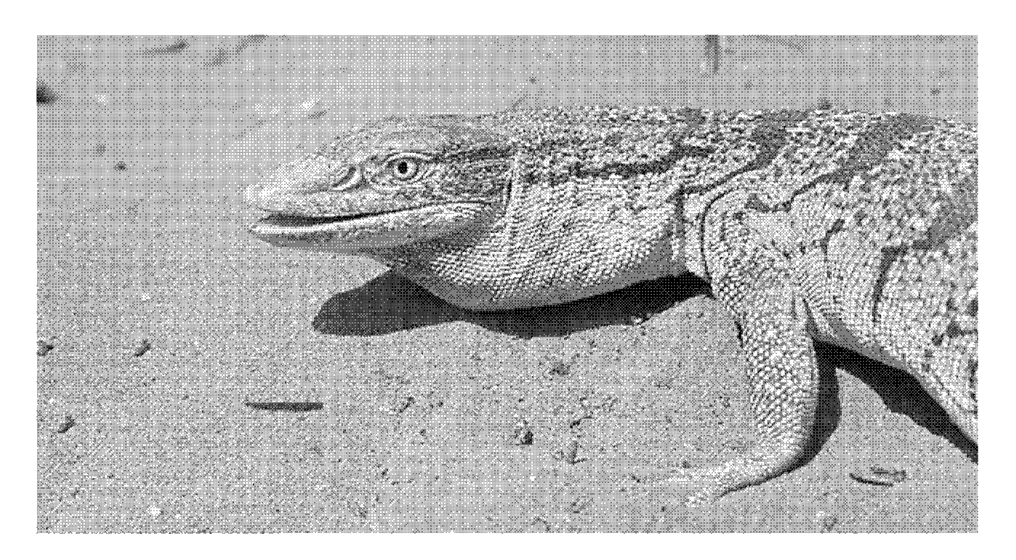


Sphenops sepsoides سحلية نعامة

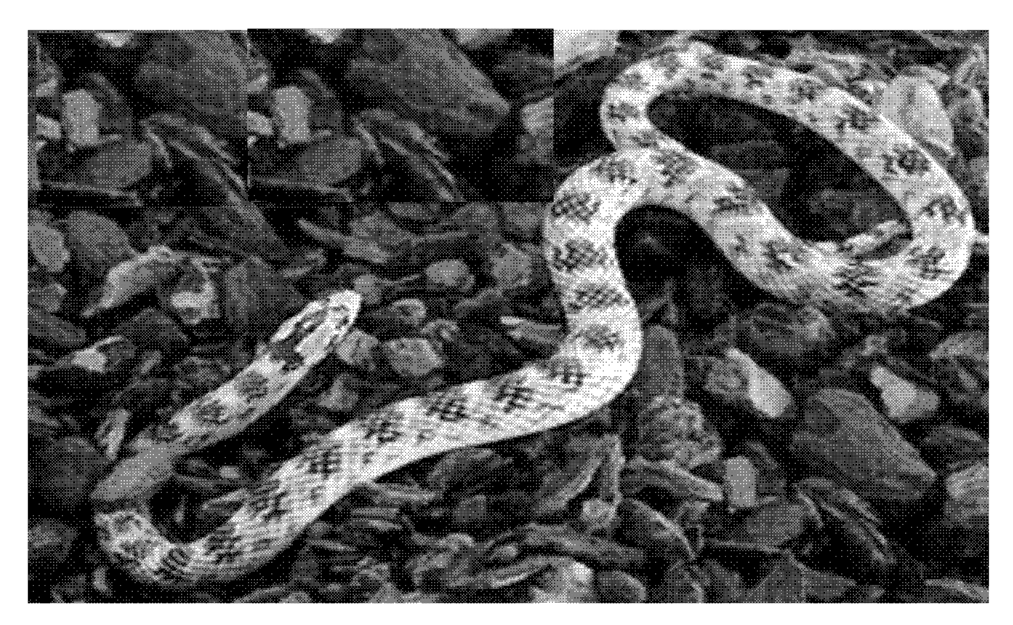


Chamaeleo chamaeleon حرباء

Plate 11.6

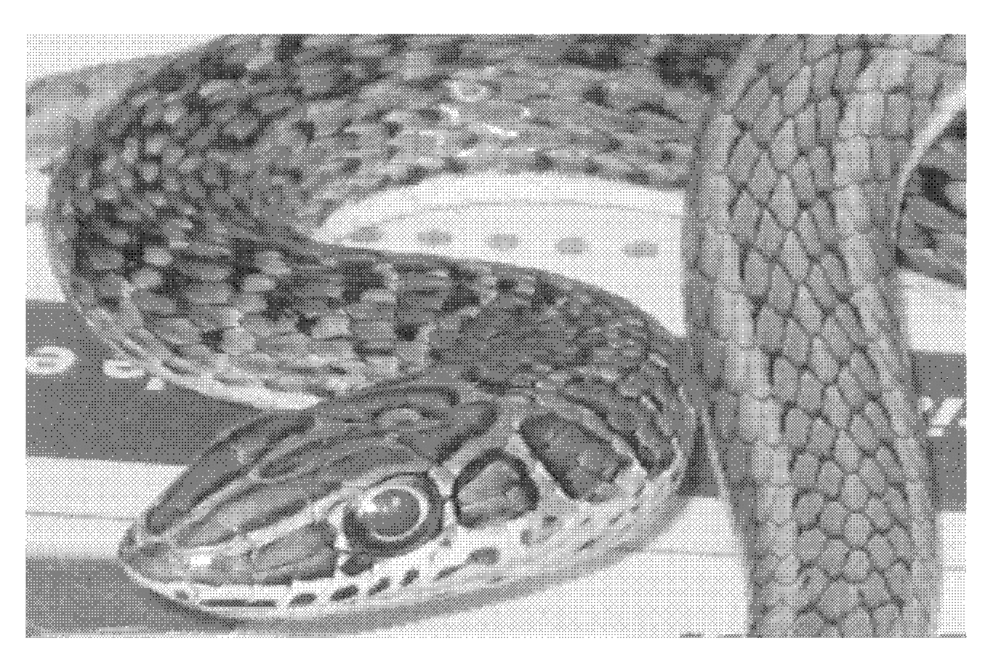


Varanus griseus ورل صحراوی

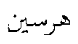


Lytorhynchus diadema بسباس

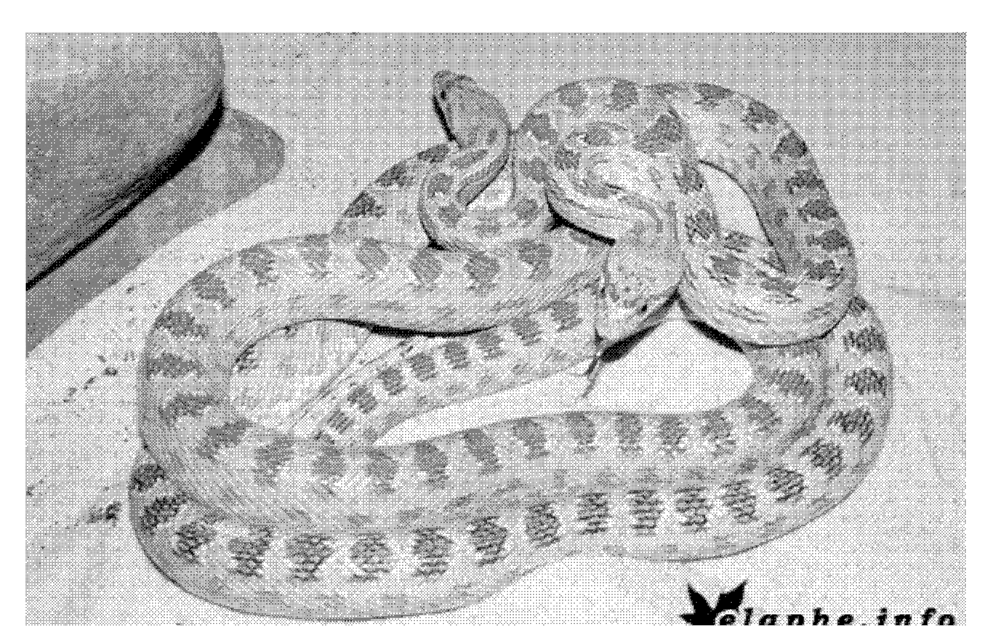
Plate 11.7



Psammophis sibilans

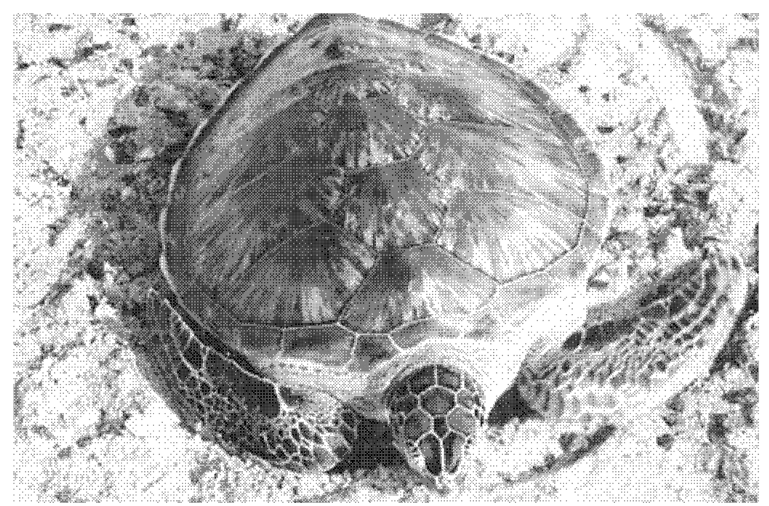


هرسين

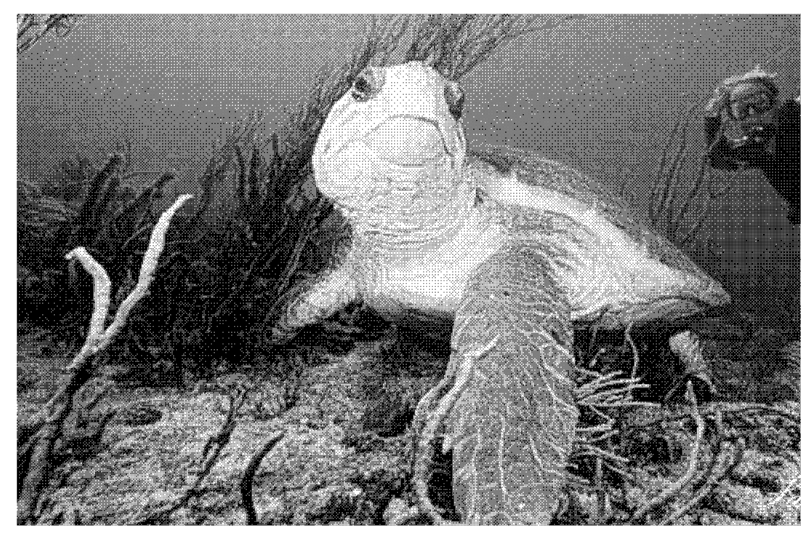


Spalerosophis diadema cliffordi أرقم احمر

Plate 11.8

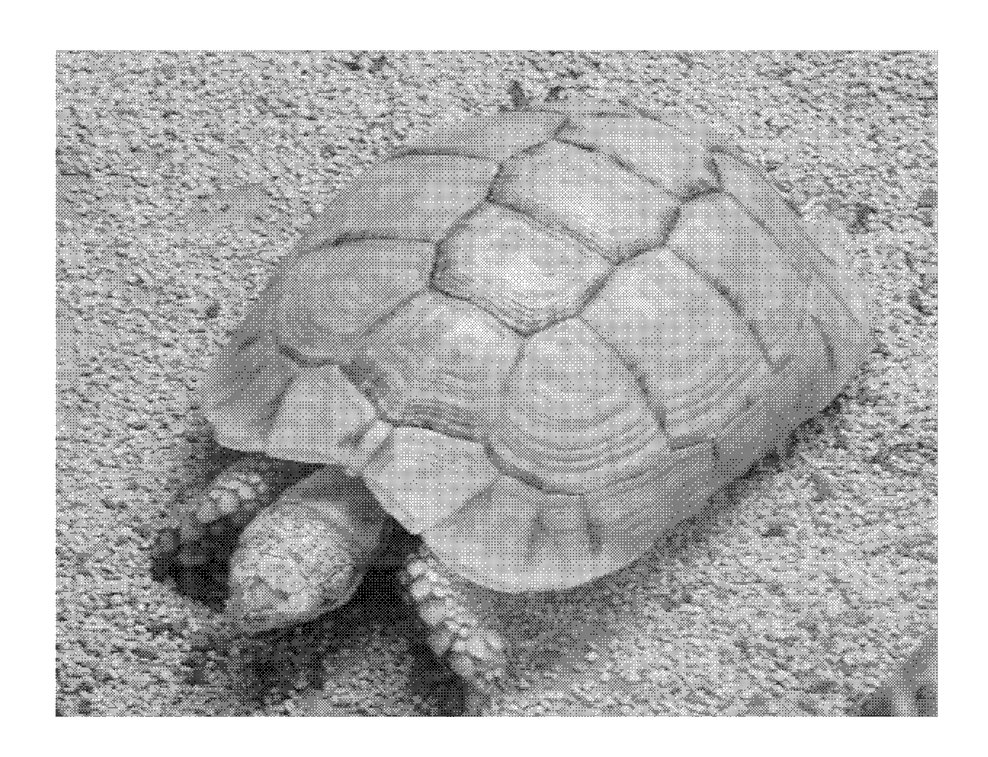


Chelonia mydas سلحفاة بحرية خضراء



Caretta caretta ترسة

Plate 11.9



Testudo kleinmanni　　　　سلحفاة مصرية

Chapter 12
Birds

12.1 PRINCIPAL AVIAN HABITATS

Fry *et al.* (1985) distinguished seven main avian habitats in Lake Bardawil: open sea, sea inlets, open water, saline tidal shallows, shelving shorelines, salt marshes and coastal dunes. The importance of these habitats for the resident and migratory birds in this lake is described in the following statements (Fry *et al.* 1985).

12.1.1 Open Sea

The open sea was not systematicaly observed for birdlife even at El Arish, but longshore flights of tens of gulls and terns were noted on most days and were thought to be local roosting and foraging movements. In spring, gannets, cormorants, pelicans, shearwaters and ducks are expected to forage in small numbers on the inshore waters.

12.1.2 Sea Inlets (Boughazes)

Lake Bardawil has four sea inlets although differing amongst themselves in physical and ornithological characteristics, they may be treated together as one main habitat type. Boughaze Abu Salah and Boughaze El-Zaranik, spaced at aproximately 2 km interval at the east of Lake Bardawil, are shallow sea entrances to Lake Zaranik along Bardawil sand bar which lacks high dunes and is almost devoid of vegetation. A few scattered foraging waders were present adjacent to each Boughaze at most visits, and small flocks of gulls and terns roosted at Boughaze El-Zaranik. Boughaze I (El-Kidwa) at the west and Boughaze II (El-Qatafa) at the middle are two human-made inlets; being wide and relatively deep, they allow more sea inwash than the other two eastern inlets. Trophic mixing supports a considerable population of gulls and terns within some 300 m of the lagoon side of both inlets, numbers varying irregularly, probably in relation to the time of the day, tide and weather.

12.1.3 Open water

Open water of Lake Bardawil has a depth of 0.5-3.0 m and with benthic patches of sea grass *Ruppia cirrhosa* and filamentous green algae. It is largely

devoid of birds, but little terns occurr sparsely, foraging across all open waters, although they keep mainly within about 100 m of strands where they rest and appear to be on the point of breeding. Common terns, sandwich terns, caspian terns and white-winged black terns were in even lower concentrations on open water. The only remaining open-water foragers noted was a single flock of white pelicans.

12.1.4 Saline Tidal Shallows

This habitat has a water depth of about 10 cm over mud and muddy sand; mainly at north-west end of Lake Zaranik and east end of Lake Bardawil, also around Likleikha and Noss Islands, between Misfaq and El-Telul, and at east end of Mallahet El-Marqab. Tens of flamingos inhabited the Bardawil - Zaranik channel and the south-east shallows of Mallahet El-Marqab. Other birds of this habitat were some hundreds of waders, mainly dunlins; and very few avocets, little egret and shelduck. Such waters are rich in dinoflagellates and blue-green algae, such as *Gomphonema aponina* and *Chroococcus turgidus* (Fouda 1985) which the flamingos are presumed to consume exploited. Dunlins and little stints, and the few curlews, greenshanks, sandpipers, wood sandpipers and ruffs encountered, foraged on wet mud and in shallows up to 2 cm deep over mud, evidently subsisting largely on mud-dwelling chironomid larvae which abounded there.

12.1.5 Shelving Shorelines

The total length of Bardawil shoreline is about 360 km. Some of the shorelines stretches are gently shelving sandy or muddy with or without backing halophytic vegetation. These stretches are exposed to predominant NW to NE wind, commonly with thanatocoenoses of *Cardium edule*, *Pirenella conica*, *P. renella caillaudi* and other molluscs (Fouda 1985), littered with inorganic flotsam of low degradibility (mainly polythene) and suffering constant wave and wavelet scouring: holding very few birds, mainly turnstones (about 20 seen on the entire lagoon). South-facing stretches, and some other strands sheltered from predominant wind, are usually polluted with tar balls but without thanatocoenoses or much litter but with a considerable population of kentish plovers and sparsely frequented by dunlines, little stints, greater sand plovers and grey plovers among others. Steeply shelving sandy shorelines, which are either exposed or sheltered, are virtually of no bird utilization.

12.1.6 Salt Marshes

Some parts of the salt marshes are dominated by woody and herbaceous halophytes (e.g. *Halocnemum strobilaceum*, *Arthrocnemum macrostachyum* and *Juncus rigidus*) growing more or less in dense cover in places overhanging water, or in belts mainly 2-20 m wide with their seaward borders usually set back a few metres from the shoreline; particularly prevalent and dense on islands of Lake Zaranik. Although removed from the aquatic ecosystem, this

halophytic vegetation, dominated by *Salicornia*-like glassworts (Chenopodiaceae), is the most important avian habitat of Lake Bardawil, affording shelter, arthropod food, and probably some plant food to numerous species of non-resident, passage migrant passerines and to breeding, sedentary larks and pipits and to kentish plovers (particularly, sparse vegetation on low dunes near dry mud flats). Six commonest passage migrants occur in this habitat (in a sequence of decreasing abundance); yellow wagtails (of at least three races: *Motacilla flava flava*, *Motacilla flava feldegg* and *Motacilla flava thunbergi*), tree pipits, red-throated pepits, blackcaps, thrush nightingales and lesser white-throats.

12.1.7 Sand Dunes

Elevated coastal dunes are covered with sparse (and locally dense) herbaceous and woody growth composed mainly of *Thylmelaea hirsuta*, *Artemisia monosperma* and *Ricinus communis*. The depressions between the elevated dunes are characterized by *Juncus subulatus*, *Cynodon dactylon*, *Phragmites australis* and *Lycium arabicum* and contain much the same resident and migratory birds as the salt marsh habitat, but in lower densities (Fouda 1985). The commonest resident species in these habitats were hoopoe lark, crested lark and tawny pipits.

Dunnet *et al.* (1985), Fry *et al.* (1985) and Varty (1990) examined the distribution of birds in relation to habitat type at Lake Bardawil, including the Zaranik area. Although these studies were conducted at different times of the year (Fry *et al.* 1985 and Varty 1990 in summer, Dunnet *et al.* 1985 and Varty 1990 in autumn), the conclusions reached by all four studies are broadly similar:

a. A few birds occur over open water areas of the Zaranik Lagoon. Some garganey has been observed to stop over on the open waters of the lagoon during autumn migration but many of these birds appear to rest on the sea off the coast (Petersen & Sorensen 1980).

b. Hypersaline shallows and salt pans also support a few birds, although these waters are rich in dinoflagellates and blue-green algae, which attract the Greater Flamingo (1,640 greater Flamingo were recorded at Lake Bardawil during summer 1990 surveys; Varty 1990). They also appear to be an important roosting area for migrating herons and white pelicans.

c. Mud flats are utilized by many more waders than other habitats at Zaranik.

d. The halophytic vegetation zone is important to migrant passerines in autumn and spring.

e. Sand dunes support low species diversity and abundance of birds, the commonest resident species being hoopoe lark (Alaemon alaudipes) and crested lark (Galerida cristatus nigricans).

12.2 AVIAN DIVERSITY

Zaranik Lagoon, as a part of Lake Bardawil, is considered to be one of the most important wetlands for waterbirds in Egypt and the eastern Mediterranean (ICBP 1989 a). Two hundred and forty-two species have been recorded from this Protected Area (51.5% of the total avian species recorded in Egypt (Goodman & Meininger 1989, Tharwat 1997, Porter & Cottridge 2000). These species belong to 121 genera, 48 families and 21 orders (Table 12.1). The well represented families are Sylviidae (26 species), Scolopacidae (25 species), Laridae (20 species), Accipitridae (18 species), Turdidae (15 species) and Anatidae (14 species). On the other hand, 18 families are represented each by only one species (Table 12.2).

A number of studies have shown that large numbers of migratory birds pass through northern Sinai in autumn where the Zaranik Lagoon and its neighboring terrain and sea shore provide an important resting and feeding site for waterbirds, e.g., the cormorant (*Phalacrocorax carbo*) and the Greater Flamingo (*Phoenicopterus ruber*) and passerines (Paran & Paz 1978, Zu-Aretz & Paran 1978, Petersen & Sorensen 1980 and 1982, Rabinowitz *et al.* 1982, Baha El Din & Salama 1984, Fry *et al.* 1985, Dunnet *et al.* 1985, Toma *et al.* 1989, Tharwat & Hamed 2000). Zaranik is regarded as a major (internationally important) breeding site for little tern (*Sterna albifrons)* and kentish plover (*Charadrius alexandrinus)* (Fry *et al.* 1985, Atta 1988 a).

A total of 205 species have been recorded at Zaranik during the period from 1973 to 1990, with goliath heron (*Ardea goliath)* and sooty gull (*Larus hemprichii)* as two doubtful additional records (Tharwat & Hamied 2000). Waterbirds (e.g. herons, ducks, terns and gulls) have been surveyed by many researchers; but Paran & Paz (1978) and Zu-Aretz & Paran (1978) did not present data on other groups of birds, such as birds of prey and passerines. Sixty-nine of these species have been recorded in seven or more of the studies and can be considered frequent visitors to the Zaranik Protected Area. The wide annual variation in numbers of birds is probably due to the difference in census timing. Zaranik is an extremely important site for garganey *Anas querquedula* (with over 220,000 recorded in some years). There are also notable numbers of white pelican (*Pelecanus onocrotalus*), night heron (*Nycticorax nycticorax*), squacco heron (*Ardeola ralloides*), little bittern (*Ixobruchus minutus*). little egret (*Egretta garzetta*), slender-billed gull (*Larus genei)*, common tern (*Sterna hirundo*), little tern (*Sterna albifrons albifrons*) and white-winged black tern (*Chlidonias leucopterus*).

Table 12.1. **Birds recorded in Zaranik Protected Area (see Tharwat & Hamied 2000)**

No.	Scientific Name	English Name	Arabic name
Order:Procellariiformes			
Family: Procellariidae			
1	*Calonectris diomedea diomedea*	Cory's Shearwater	جلم الماء الكبير
2	*Puffinus griseus*	Sooty Shearwater	جلم الماء الأسحم
3	*Puffinus puffinus yelkouan*	Manx Shearwater	جلم الماء
Order: Podiccipediformes			
Family: Podicipedae			
4	*Podiceps cristatus cristatus*	Great Crested Grebe	غطاس متوج
5	*Podiceps nigricollis nigricollis*	Black-necked Grebe	غطاس أسود الرقبة
6	*Tachybaptus ruficollis ruficollis*	Little Grebe	زهوت
Order: Pelecaniformes			
Family: Phalacrocoracidae			
7	*Phalacrocorax carbo sinensis*	Cormorant	غراب البحر - أبو غطاس
Family: Sulidae			
8	*Sula bassana bassana*	Gannet	أطيش أبيض
Family: Pelecanidae			
9	*Pelecanus onocrotalus*	White Pelican	جمل البحر – بجع أبيض
Order: Ciconiiformes			
Family: Ardeidae			
10	*Ardea cinerea cinerea*	Grey Heron	بلشون رمادى
11	*Ardea goliath*	Goliath Heron	بلشون جبار – مرة
12	*Ardea purpurea purpurea*	Purple Heron	مالك الحزين – جحفة
13	*Ardeola ralloides*	Squacco Heron	واق أبيض
14	*Botaurus stellaris stellaris*	Bittern	واق – بوبو – عجاج – بغيغ
15	*Egretta alba alba*	Great White Egret	بلشون أبيض كبير
16	*Egretta garzetta garzetta*	Little Egret	بلشون أبيض - أبو بليقة
17	*Egretta ibis ibis*	Cattle Egret	أبو قردان - غرنوج
18	*Ixobruchus minutus minutus*	Little Bittern	واق صغير - مليحة
19	*Nycticorax nycticorax nycticorax*	Night Heron	غراب الليل – واق الشجر
Family: Ciconiidae			
20	*Ciconia ciconia ciconia*	White Stork	عنز – لقلق أبيض
21	*Ciconia nigra*	Black Stork	عنز اسود – لقلق أسود
Family: Threskiornithidae			
22	*Plegadis falcinellus*	Glossy Ibis	أبو منجل أسود
23	*Platalea leucordia leucordia*	Spoonbill	أبو ملعقة
Order: Phoenicopteriformes			
24	*Phoenicopterus ruber roseus*	Greater Flamingo	بشاروش - نحام
Order: Anseriformes			
Family: Anatidae			
25	*Anas acuta acuta*	Pintail	بلبول
26	*Anas angustirostris*	Marbled Duck	شرشير مخطط - منيا
27	*Anas clypeata*	Shoveler	كبش
28	*Anas crecca crecca*	Teal	شرشير شتوى
29	*Anas penelope*	Wigeon	صواى
30	*Anas platyrhynchos platyrhynchos*	Mallard	خضارى
31	*Anas querquedula*	Garganey	شرشير صيفى
32	*Anas strepera strepera*	Gadwall	سمارى
33	*Aythya ferina*	Common Pochard	حمراى
34	*Aythya fuligula*	Tufted Duck	زرقاى
35	*Aythya nyroca*	Ferruginous Duck	زرقاى أخضر
36	*Mergus serrator serrator*	Red-breasted Merganser	بلقشة حمراء الصدر
37	*Netta rufina*	Red-crested Pochard	ونس
38	*Tadorna tadorna*	Common Shelduck	شهرمان
Order: Accipitriformes			
Family: Accipitridae			
39	*Accipiter nisus nisus*	Sparrowhawk	باشق
40	*Accipiter brevipes*	Levant Sparrowhawk	باز – بيدق – باشق

No.	Scientific Name	English Name	Arabic name
41	*Aquila heliaca heliaca*	Imperial Eagle	عقاب نلكى – خطية
42	*Aquila nipalensis orientalis*	Steppe Eagle	
43	*Aquila pomarina pomarina*	Lesser Spotted Eagle	عقاب سفعاء صغرى
44	*Buteo buteo vulpinus*	Buzzard	صقر حوام
46	*Buteo rufinus rufinus*	Long-legged Buzzard	صقر جراح
47	*Circaetus gallicus gallicus*	Short-toed Eagle	
48	*Circus aeruginosus aeruginosus*	Marsh Harrier	دراع
49	*Circus cyaneus cyaneus*	Hen Harrier	أبو حسن ـ عقاب الدجاج
50	*Circus macrourus*	Pallid Harrier	مرزة بغشاء
51	*Circus pygargus*	Montagu's Harrier	أبو شردة
52	*Gyps fulvus fulvus*	Griffon Vulture	نسر اسمر
53	*Hieraaetus pennatus pennatus*	Booted Eagle	عقاب مسيرة صغيرة
54	*Milvus migrans migrans*	Black Kite	حداية سوداء
55	*Neophron percnopterus percnopterus*	Egyptian Vulture	رخمة مصرية – أنواق
56	*Pernis apivorus apivorus*	Honey Buzzard	حوام النحل
	Family: Pandionidae		
57	*Pandion haliaetus haliaetus*	Osprey	منسورى – نسورى
Order: Falconiformes			
	Family: Falconidae		
58	*Falco biarmicus tanypterus*	Lanner	صقر حر
59	*Falco cherrug cherrug*	Saker	صقر الغزال
60	*Falco columbarius aesalon*	Merlin	يؤيؤ – أبو رية
61	*Falco concolor*	Sooty Falcon	صقر الغروب
62	*Falco eleonorae*	Eleonora's Falcon	صقر اسحم – ابو حوام
63	*Falco naumanni naumanni*	Lesser Kestrel	عوسق صغير – صقر الجراد
64	*Falco peregrinus peregrinus*	Peregrine Falcon	شاهين
65	*Falco subbuteo subbuteo*	Hobby	كونج
66	*Falco tinnunculus tinnunculus*	Kestrel	عوسق
67	*Falco vespertinus vespertinus*	Red-footed Falcon	لزيق
Order: Galliformes			
	Family: Phasianidae		
68	*Coturnix coturnix coturnix*	Quail	سلوى – سمان
Order: Gruiformes			
	Family: Gruidae		
69	*Grus grus grus*	Crane	كركى – رهو ـ غرنوج
	Family: Rallidae		
70	*Crex crex*	Corncrake	مرعة الغلة
71	*Fulica atra atra*	Coot	غر
72	*Gallinula chloropus chloropus*	Moorhen	دجاجة الماء
73	*Porzana prava*	Little Crake	مرعة صغيرة
74	*Rallus aquaticus aquaticus*	Water Rail	مرعة الماء ـ كلب الماء
Order: Chardriiformes			
	Family: Rostratulidae		
75	*Rostratula benghalensis benghalensis*	Painted Snipe	بكاشين مزوق ـ شنقب
	Family: Haematopodidae		
76	*Haematopus ostralegus ostralegus*	Oystercatcher	آكل المحار – بجع البحر
	Family: Recurvirostridae		
77	*Himantopus himantopus himantopus*	Black-winged Stilt	أبو المغازل ـ أبو قصبة
78	*Recurvirostra avosetta*	Avocet	حليبى ـ نكات
79	*Burhinus oedicnemus oedicnemus*	Common Thick-knee	كروان جبلى
	Family: Glareolidae		
80	*Cursorius cursor cursor*	Cream-coloured Courser	الجليل - جروان
81	*Glareola nordmanni*	Black-winged Pratincole	
82	*Glareola pratincola pratincola*	Collared Pratincole	أبو اليسر
	Family: Charadriidae		
83	*Charadrius alexandrinus alexandrinus*	Kentish Plover	قطقاط أبو الرؤوس
84	*Charadrius dubius curonicus*	Little Ringed Plover	قطقاط متوج صغير
85	*Charadrius hiaticula tundrae*	Ringed Plover	قطقاط متوج كبير ـ زقزاق
86	*Charadrius leschenaultii*	Greater Sand Plover	قطقاط الرمل الكبير

No.	Scientific Name	English Name	Arabic name
87	*Chettusia leucura*	White-tailed Plover	زقزاق أبيض الذنب
88	*Eudromias morinellus*	Dotterel	قطقاط أغبر
89	*Hoplopterus spinosus*	Spur-winged Plover	زقزاق - أبو زفر
90	*Pluvialis apricaria apricaria*	Golden Plover	قطقاط ذهبى
91	*Pluvialis squatarola squatarola*	Grey Plover	قطقاط رمادى
92	*Vanellus vanellus*	Lapwing	زقزاق شامى
Family: Scolopacidae			
93	*Actitis hypoleucos*	Common Sandpiper	طيطوى
94	*Arenaria interpres interpres*	Turnstone	قنبرة الماء
95	*Calidris alba*	Sanderling	مدروان
96	*Calidris alpina alpina*	Dunlin	دريجة
97	*Calidris canutus canutus*	Knot	دريجة الشمال
98	*Calidris ferruginea*	Curlew Sandpiper	دريجة كروانية
99	*Calidris minuta*	Little Stint	كروان الماء
10	*Calidris temminckii*	Temminck's Stint	فطيرة تمنك
10	*Gallinago gallinago gallinago*	Snipe	بكاشين - شنقب
10	*Gallinago media*	Great Snipe	شنقب كبير
10	*Limicola falcinellus falcinellus*	Broad-billed Sandpiper	طيطوى عريض المنقار
10	*Limosa lapponica lapponica*	Bar-tailed Godwit	بقويقة مخططة الذنب
10	*Limosa limosa limosa*	Black-tailed Godwit	بقويقة سوداء الذنب
10	*Lymnocryptes minimus*	Jack Snipe	بكاشين صغير
10	*Numenius arquata arquata*	Curlew	كروان الغيط
108	*Numenius phaeopus phaeopus*	Whimbrel	كروان غيطى صغير – كروان
10	*Numenius tenuirostris*	Slender-billed Curlew	كروان الماء رفيع المنقار
11	*Philomachus pugnax*	Ruff	بياض - حجوالة
111	*Tringa erythropus*	Spotted Redshank	طيطوى أحمر الساق أرقط
112	*Tringa glareola*	Wood Sandpiper	طيطوى الغياض
113	*Tringa nebularia*	Greenshank	طيطوى أخضر الساق
114	*Tringa ochropus*	Green Sandpiper	طيطوى أخضر
115	*Tringa stagnatilis*	Marsh Sandpiper	طيطوى المستنقع
116	*Tringa totanus totanus*	Redshank	طيطوى أحمر الساق
117	*Xenus cinereus*	Terek Sandpiper	طيطوى نكات
Family: Phalaropodidae			
118	*Phalaropus fulicarius*	Grey Phalarope	فلاروب رمادى
119	*Phalaropus lobatus*	Red-necked Phalarope	فلاروب احمر العنق
Family: Stercorariidae			
120	*Stercorarius longicaudus*	Long-tailed Skua	كركر طويل الذنب
121	*Stercorarius parasiticus*	Arctic Skua	كركر قطبى
122	*Stercorarius pomarinus*	Pomarine Skua	كركر
Family: Laridae			
123	*Chlidonias hybrida hybrida*	Whiskered Tern	خطاف أبيض الخد
124	*Chlidonias leucoptera*	White-winged Black Tern	خطاف أسود الجناح - أبو دفة
125	*Chlidonias niger niger*	Black Tern	خطاف أسود - خرشنة
126	*Gelochelidon nilotica nilotica*	Gull-billed Tern	خطاف نورسى المنقار – اويق
127	*Larus audouinii*	Audouin's Gull	نورس أدوين
128	*Larus argentatus cachinnans*	Yellow-legged Gull	نورس أصفر القدم
129	*Larus canus canus*	Common Gull	نورس شاع - زمج الماء
130	*Larus fuscus fuscus*	Lesser Black-backed Gull	نورس دغبة - جوكة
131	*Larus genei*	Slender-billed Gull	نورس قرقطى
132	*Larus hemprichii*	Sooty Gull	نورس اسحم
133	*Larus ichthyaetus*	Great Black-headed Gull	نورس السمك
134	*Larus melanocephalus*	Mediterranean Gull	نورس البحر المتوسط
135	*Larus minutus*	Little Gull	نورس صغير
136	*Larus ridibundus*	Black-headed Gull	نورس أسود الرأس
137	*Rissa tridactyla tridactyla*	Black-legged Kittiwake	نورس اسود القدم
138	*Sterna albifrons albifrons*	Little Tern	خطاف صغير - دغبز
139	*Sterna bengalensis par*	Lesser Crested Tern	خرشنة
140	*Sterna caspia caspia*	Caspian Tern	خطاف ابو بلحة– خطاف ابو
141	*Sterna hirundo hirundo*	Common Tern	خطاف البحر

No.	Scientific Name	English Name	Arabic name
142	*Thalasseus sandvicensis sandvicensis*	Sandwich Tern	خطاف البحر
Order: Pteroclidiformes			
	Family: Pteroclididae		
143	*Pterocles senegallus*	Spotted Sandgrouse	قطا ارقط
Order: Columbiformes			
	Family: Columbidae		
144	*Columba oenas oenas*	Stock Pigeon	حمام برى – يمام – الورقة
145	*Streptopelia turtur arenicola*	Turtle Dove	قمرى – ترجول
146	*Streptopelia decaocto decaocto*	Collared Dove	يمام مطوق
147	*Streptopelia senegalensis aegyptiaca*	Palm Dove	يمام بلدى
148	*Streptopelia senegalensis senegalensis*	Laughing Dove	يمام بلدى
Order: Cuculiformes			
	Family: Cuculidae		
149	*Clamator glandarius*	Great Spotted Cuckoo	قميحة – وقواق ارقط
150	*Cuculus canorus*	Cuckoo	هوهو – وقواق
Order: Strigiformes			
	Family: Strigidae		
151	*Asio flammeus flammeus*	Short-eared Owl	هامة
152	*Asio otus otus*	Long-eared Owl	بومة طويلة الأذن
153	*Athene noctua saharae*	Little Owl	أم الصخر
154	*Otus scops scops*	Scops Owl	ثيج- بوة – سياج – ثياج
Order: Caprimulgiformes			
	Family: Caprimulgidae		
155	*Caprimulgus europaeus meridionalis*	Nightjar	ابو النوم – سيد – قرة
Order: Apodiformes			
	Family: Apodidae		
156	*Apus apus apus*	Swift	سمامة
Order: Coraciiformes			
	Family: Coraciidae		
157	*Coracias garrulus garrulus*	Roller	غراب زيتونى
	Family: Alcedinidae		
158	*Alcedo atthis atthis*	Kingfisher	صياد السمك ـ رفراف
159	*Halcyon smyrnensis smyrenensis*	White-breasted Kingfisher	قاوند
	Family: Meropidae		
160	*Merops apiaster*	Bee-eater	وروار اوربى – عصفور الجنة
	Family: Upupidae		
161	*Upupa epops epops*	Hoopoe	هدهد
Order: Piciformes			
	Family: Picidae		
162	*Jynx torquilla torquilla*	Wryneck	لواء – ام الواء
Order: Passeriformes			
	Family: Hirundinidae		
163	*Delichon urbica urbica*	House Martin	سنونو ابيض البطن
164	*Hirundo daurica rufula*	Red-rumped Swallow	عصفور الجنة احمر العجز
165	*Hirundo rustica savignii*	Swallow	عصفور الجنة
166	*Ptyonoprogne rupestris rupestris*	Crag Martin	سنونو الصخر
167	*Riparia riparia shelleyi*	Sand Martin	سنونو الشواطىء
	Family: Alaudidae		
168	*Alaemon alaudipes alaudipes*	Hoopoe Lark	مكاة – ابو خميرة
169	*Alauda arvensis cantarella*	Skylark	قنبرة الغيط
170	*Ammomanes cincturus arenicolor*	Bar-tailed Desert Lark	قنبرة الصحراء موشمة الذنب
171	*Calandrella cinerea brachydactyla*	Short-toed Lark	قنبرة قصيرة الأصابع
172	*Galerida cristata maculata*	Crested Lark	قنبرة بشوشة – قنبرة متوجة
	Family: Motacillidae		
173	*Anthus campestris campestris*	Tawny Pipit	ابو فصية الصحراء
174	*Anthus cervinus*	Red-throated Pipit	بو فصية أحمر الزور
175	*Anthus pratensis pratensis*	Meadow Pipit	ابو فصية الغيط
176	*Anthus spinoletta coutellii*	Water (Rock) Pipit	ابو فصية الماء
177	*Anthus trivialis*	Tree Pipit	ابو فصية الشجر

No.	Scientific Name	English Name	Arabic name
178	*Motacilla alba alba*	White Wagtail	أبو فصادة أبيض
179	*Motacilla cinerea cinerea*	Grey Wagtail	أبو فصادة رمادى
180	*Motacilla flava pygmaea*	Yellow Wagtail	أبو فصادة مصرى
	Family: Laniidae		
181	*Lanius collurio collurio*	Red-backed Shrike	دقناش أكحل
182	*Lanius excubitor elegans*	Great Grey Shrike	دقناش البادية
183	*Lanius minor minor*	Lesser Grey Shrike	دقناش صردى
184	*Lanius nubicus*	Masked Shrike	دقناش قبطى
185	*Lanius senator senator*	Woodchat	دقناش اوربى – دقناش شامى
	Family: Oriolidae		
186	*Oriolus oriolus oriolus*	Golden Oriole	عصفور التوت – صفير – ابو
	Family: Corvidae		
187	*Corvus corone cornix*	Hooded Crow	قاق - غراب بلدى
188	*Corvus ruficollis ruficollis*	Brown-necked Raven	غراب نوحى
	Family: Sylviidae		
189	*Acrocephalus arundinaceus*	Great Reed Warbler	هازجة القصب الكبير
190	*Acrocephalus palustris*	Marsh Warbler	هازجة البطانح
No	**Scientific Name**	**English Name**	**Arabic name**
191	*Acrocephalus schoenobaenus*	Sedge Warbler	هازجة السعد – وش الديبة
192	*Acrocephalus scripaceus fusca*	Reed Warbler	هازجة الغاب – ابو دخنة –
193	*Acrocephatus melanopogon*	Moustached Warbler	هازجة ام شارب
194	*Cercotrichas galactotes galactotes*	Rufous Bush Robin	البلبل الأحمر المغنى– دخلة
195	*Cettia cettia orientalis*	Cetti's Warbler	مغنى ستى
196	*Hippolais olivetorum*	Olive-tree Warbler	خنشع الزيتون الكبير
197	*Hippolais pallida elaeica*	Olivaceous Warbler	خنشع زيتونى – زق
198	*Locustella fluviatilis*	River Warbler	هازجة النهر
199	*Locustella luscinioides luscinioides*	Savi's Warbler	بلبل الغاب – هازجة المستنقع
200	*Phylloscopus bonelli bonelli*	Bonelli's Warbler	نقشارة صفراء العجز
201	*Phylloscopus collybita collybita*	Chiffchaff	سكسة - شادية الخمايل
202	*Phylloscopus sibilatrix*	Wood Warbler	نقشارة الشجر
203	*Phylloscopus trochilus trochilus*	Willow Warbler	نقشارة الصفصاف
204	*Prinia gracilis gracilis*	Graceful Prinia	فصية – هازجة
205	*Prinia gracilis palestine*	Graceful Warbler	فصية - هازجة
206	*Sylvia atricapilla atricapilla*	Blackcap	ابو قلنسوة – دبسية
207	*Sylvia borin borin*	Garden Warbler	دخلة كحلة-دخلة البساتين-
208	*Sylvia cantillans albistriata*	Subalpine Warbler	دخلة الصرود
209	*Sylvia communis communis*	Whitethroat	زريقة فيرانى
210	*Sylvia conspicillata conspicillata*	Spectacled Warbler	دخلة ام نظارة
211	*Sylvia curruca curruca*	Lesser Whitethroat	زريقة فيرانى – دخلة فيرانى
212	*Sylvia melanocephala melanocephala*	Sardinian Warbler	دخلة رأساء
213	*Sylvia nisoria nisoria*	Barred Warbler	دخلة مخططة
214	*Sylvia ruppelli ruppelli*	Ruppell's Warbler	زريقة قصابى
	Family: Muscicapidae		
215	*Ficedula albicollis albicollis*	Collared Flycatcher	خاطف الذباب المطوق
216	*Ficedula albicollis semitorquata*	Semi-collared	خاطف الذباب شبه المطوق
217	*Ficedula hypoleuca hypoleuca*	Pied Flycatcher	خاطف الذباب الأبقع – شورب
218	*Ficedula prava prava*	Red-breasted	خاطف الذباب احمر الصدر
219	*Muscicapa striata striata*	Spotted Flycatcher	خاطف الذباب الأنقط
	Family: Turdidae		
220	*Luscinia luscinia*	Thrush Nightingale	عندليب
221	*Luscinia megarhynchos megarhynchos*	Nightingale	المغناء الأسمر – هزاز - عتباز
222	*Luscinia svecica svecica*	Bluethroat	حسينى
223	*Monticola saxatilis saxatilis*	Rock Thrush	سكالة- أبو شوك – أبو سكلة
224	*Monticola solitarius solitarius*	Blue Rock Thrush	حمامة زرقاء – سكلة زرقاء
225	*Oenanthe deserti homachroa*	Desert Wheatear	أبلق الصحراء - أبوزارا
226	*Oenanthe hispanica melanoleuca*	Black-eared	أبلق اسود الأذن
227	*Oenanthe isabellina*	Isabelline Wheatear	أبلق أشهب
228	*Oenanthe lugens halophila*	Mourning Wheatear	أبلق حزين
229	*Oenanthe oenanthe oenanthe*	Wheatear	أبلق ابو بليق

No.	Scientific Name	English Name	Arabic name
230	*Phoenicurus phoenicurus phoenicurus*	Redstart	حميراء
231	*Saxicola rubetra rubetra*	Whinchat	قليعى أحمر - فستوقة
232	*Saxicola torquata rubicola*	Stonechat	قليعى مطوق
233	*Turdus merula merula*	Blackbird	شحرور
234	*Turdus philomelos philomelos*	Song Thrush	سمنة مطربة
	Family: Passeridae		
235	*Passer domesticus niloticus*	House Sparrow	عصفور دورى - عصفور الغيط
236	*Passer hispaniolensis hispaniolensis*	Spanish Sparrow	عصفور أسبانى
	Family: Fringillidae		
237	*Carduelis chloris aurantiiventris*	Greenfinch	عصفور خضيرى
238	*Carduelis carduelis niediecki*	Goldfinch	عصفور حسون-ابو سقاية-ابو
	Family: Emberizidae		
239	*Emberiza caesia*	Cretzschmar's	درسة زرقاء الرأس
240	*Emberiza calandra calandra*	Corn Bunting	درسة
241	*Emberiza hortulana*	Ortolan Bunting	درسة الشعير
242	*Emberiza melanocephala*	Black-headed	درسة سوداء الرأس

Of the 242 species and subspecies recorded in Lake Bardawil, 67 are residents(27.7%). The migratory birds represent about 72.3% of the total recorded species in Zaranik (Table 12.3). Out of 17 bird species listed in Egypt as endimic species, the collection of information about the national and world distribution of the birds in Lake Bardawil indicated the possibility of occurrence of only one endemic species: *Streptopelia senegalensis aegyptiaca*, (Table 12.4).

There are 10 globally threatened bird species occurring in Egypt (IUCN, Red List of Threatened Animals). These species are: dalmatian pelican (*Pelecanus crispus*), marbled teal (*Marmaronetta angustirostris*), white-headed duck (*Oxyura leucocephala*), cinereous vulture (*Aegypius monachus*), imperial eagle (*Aquila heliaca*), lesser kestrel (*Falco naumanni*), corncrake (*Crex crex*), little bustard (*Otis tetrax*), white-eyed gull (*Larus leucophthalmus*) and audouin's gull (*Larus audouinii*).

12.3 SEASONAL VARIATIONS

12.3.1 Autumn

51 species were recorded during the study of Tharwat & Hamied (2000) in autumn 2000, 13 of them are considered rare species (according to Goodman *et al.* 1989): *Crex crex* (corncrake), *Numenius arquata arquata* (common curlew), *Limosa lapponica lapponica* (bar-tailed godwit), *Haematopus ostralegus ostralegus* (european oystercatcher), *Arenaria interpres interpres* (turnstone), *Numenius phaeopus phaeopus* (whimbrel), *Plegadis falcinellus* (glossy ibis), *Lanius collurio isabellinus* (isabelline shrike), *Gelochelidon n. nilotica* (gull-billed tern), *Egretta a. alba* (great white egret), *Porzana parva* (little crake), *Hydroprogne caspia caspia* (caspian tern) *and Sterna bengalensis par* (lesser crested tern).

Order	Family	Characteristic group	Genera	Species
Procellariiformes	**Procellariidae**	**Shearwaters, petrels, fulmars**	**2**	**3**
Podiccipediformes	**Podicipedidae**	**Topic birds**	**2**	**3**
Pelecaniformes	**Phalacrocoracidae**	**Cororants**	**1**	**1**
	Sulidae	**Gannets, boobies**	**1**	**1**
	Pelecanidae	**Pelicans**	**1**	**1**
Ciconiiformes	**Ardeidae**	**Herones, bitterns**	**6**	**10**
	Ciconiidae	**Storks**	**1**	**2**
	Threskiornithidae	**Ibises, spoonbills**	**2**	**2**
Phoenicopteriformes			**1**	**1**
Anseriformes	**Anatidae**	**Ducks, geese, swans**	**5**	**14**
Accipitriformes	**Accipitridae**	**Vultures, eagles, kites, harriers**	**10**	**18**
	Pandionidae	**Osprey**	**1**	**1**
Falconiformes	**Falconidae**	**Falcons, caracaras**	**1**	**10**
Galliformes	**Phasianidae**	**Pheasants, quial, peafowl**	**1**	**1**
Gruiformes	**Gruidae**	**Cranes**	**1**	**1**
	Rallidae	**Rails, gallinules, coots**	**5**	**5**
Chardriiformes	**Rostratulidae**	**Painted snipes**	**1**	**1**
	Haematopodidae	**Oystercatchers**	**1**	**1**
	Recurvirostridae	**Avocets, stilts**	**2**	**2**
	Burhinidae	**Thick-knees, stone curlews**	**1**	**1**
	Glareolidae	**Pratincoles, coursers**	**1**	**3**
	Charadriidae	**Plovers, lapwings**	**6**	**10**
	Scolopacidae	**Sandpipers, snipes, turnstones**	**11**	**25**
	Phalaropodidae	**Phalaropes**	**1**	**2**
	Stercorariidae	**Skuas, Jaegera**	**1**	**3**
	Laridae	**Gulls, terns**	**6**	**20**
Pteroclidiformes	**Pteroclididae**	**Sandgrouse**	**1**	**1**
Columbiformes	**Columbidae**	**Pigeons, doves**	**2**	**5**
Cuculiformes	**Cuculidae**	**Cuckoos, anis, roadrunners**	**2**	**2**
Strigiformes	**Strigidae**	**Typical owls**	**3**	**4**
Caprimulgiformes	**Caprimulgidae**	**Nightjars, goatsuckers, nighthawks**	**1**	**1**
Apodiformes	**Apodidae**	**Swifts**	**1**	**1**
Coraciiformes	**Coraciidae**	**Rollers**	**1**	**1**
	Alcedinidae	**Kingfishers**	**2**	**2**
	Meropidae	**Bee-caters**	**1**	**1**
	Upupidae	**Hoopoes**	**1**	**1**
Piciformes	**Picidae**	**Woodpeckers, piculets, wrynecks**	**1**	**1**
Passeriformes	**Hirundinidae**	**Swallows**	**4**	**5**
	Alaudidae	**Larks**	**5**	**5**
	Motacillidae	**Pipits, wagtails**	**2**	**8**
	Laniidae	**Shrikes**	**1**	**5**
	Oriolidae	**Orioles**	**1**	**1**
	Corvidae	**Crows, jays, magpies**	**1**	**2**
	Sylviidae	**Old world warblers**	**8**	**26**
	Muscicapidae	**Old world fly catchers**	**2**	**5**
	Turdidae	**Thrushes, nightingales, wheatears,**	**6**	**15**
	Passeridae	**Sparrows**	**1**	**2**
	Fringillidae	**Finches**	**1**	**2**
	Emberizidae	**Buntings, sparrows, cardinals**	**1**	**4**

20 Total	48	121		242

Table 12.2. **Taxonomic diversity of avifauna in Lake Bardawil.**

Table 12.3. **Status of the bird species recorded in Lake Bardawil (after Goodman *et al.* 1989, Tharwat 1997). W: winter, Sp: spring, Su: summer and Au: autumn.**

No.	Scientific name	Resident	Visitor		Passer		Total
			W	Sp	Su	Au	
1	*Calonectris diomedea diomedea*		+		+		2
2	*Puffinus griseus*				+	+	2
3	*Puffinus puffinus yelkouan*		+		+	+	3
4	*Podiceps cristatus cristatus*		+				1
5	*Podiceps nigricollis nigricollis*		+				1
6	*Tachybaptus ruficollis ruficollis*	+					1
7	*Phalacrocorax carbo sinensis*		+	+	+	+	4
8	*Sula bassana bassana*		+		+	+	3
9	*Pelecanus onocrotalus*		+		+	+	3
10	*Ardea cinerea cinerea*	+	+	+			3
11	*Ardea goliath*	+	+	+			3
12	*Ardea purpurea purpurea*		+	+	+	+	4
13	*Ardeola ralloides*	+	+		+	+	4
14	*Botaurus stellaris stellaris*		+	+			2
15	*Egretta alba alba*		+		+	+	3
16	*Egretta garzetta garzetta*	+	+		+	+	4
17	*Egretta ibis ibis*	+	+		+	+	4
18	*Ixobruchus minutus minutus*	+	+		+	+	4
19	*Nycticorax nycticorax nycticorax*	+	+		+	+	4
20	*Ciconia ciconia ciconia*		+	+	+	+	4
21	*Ciconia nigra*		+	+	+	+	4
22	*Plegadis falcinellus*		+		+	+	3
23	*Platalea leucordia leucordia*	+	+	+	+	+	5
24	*Phoenicopterus ruber roseus*	+	+				2
25	*Anas acuta acuta*		+		+	+	3
26	*Anas angustirostris*	+					1
27	*Anas clypeata*		+		+	+	3
28	*Anas crecca crecca*		+		+	+	3
29	*Anas penelope*		+		+	+	3
30	*Anas platyrhynchos platyrhynchos*	+	+		+	+	4
31	*Anas querquedula*				+	+	2
32	*Anas strepera strepera*		+		+	+	3
33	*Aythya ferina*		+		+	+	3
34	*Aythya fuligula*		+		+	+	3
35	*Aythya nyroca*		+		+	+	3
36	*Mergus serrator serrator*		+				1
37	*Netta rufina*		+				1
38	*Tadorna tadorna*		+				1
39	*Accipiter nisus nisus*		+		+	+	3
40	*Accipiter brevipes*				+	+	2
41	*Aquila heliaca heliaca*		+		+	+	3
42	*Aquila nipalensis orientalis*		+	+	+	+	4
43	*Aquila pomarina pomarina*		+		+	+	3
44	*Buteo buteo vulpinus*				+	+	2
46	*Buteo rufinus rufinus*	+	+		+	+	4
47	*Circactus gallicus gallicus*	+					1

No.	Scientific name	Resident	Visitor		Passer		Total
			W	Sp	Su	Au	
48	*Circus aeruginosus aeruginosus*		+		+	+	3
49	*Circus cyaneus cyaneus*		+		+	+	3
50	*Circus macrourus*		+		+	+	3
51	*Circus pygargus*		+		+	+	3
52	*Gyps fulvus fulvus*		+				1
53	*Hieraaetus pennatus pennatus*		+		+	+	3
54	*Milvus migrans migrans*	+			+	+	3
55	*Neophron percnopterus percnopterus*	+					1
56	*Pernis apivorus apivorus*		+		+	+	3
57	*Pandion haliaetus haliaetus*	+	+		+	+	4
58	*Falco biarmicus tanypterus*	+					1
59	*Falco cherrug cherrug*		+		+	+	3
60	*Falco columbarius acsalon*		+				1
61	*Falco concolor*			+			1
62	*Falco eleonorae*				+	+	2
63	*Falco naumanni naumanni*	+	+		+	+	4
64	*Falco peregrinus peregrinus*		+		+	+	3
65	*Falco subbuteo subbuteo*			+	+	+	3
66	*Falco tinnunculus tinnunculus*	+					1
67	*Falco vespertinus vespertinus*			+	+	+	3
68	*Coturnix coturnix coturnix*	+	+		+	+	4
69	*Grus grus grus*		+		+	+	3
70	*Crex crex*				+	+	2
71	*Fulica atra atra*	+	+	+			3
72	*Gallinula chloropus chloropus*	+	+		+	+	4
73	*Porzana prava*		+		+	+	3
74	*Rallus aquaticus aquaticus*	+	+				2
75	*Rostratula benghalensis benghalensis*	+					1
76	*Haematopus ostralegus ostralegus*		+	+	+	+	4
77	*Himantopus himantopus himantopus*	+	+		+	+	4
78	*Recurvirsotra avosctta*	+	+	+			3
79	*Burhinus oedicnemus oedicnemus*	+	+				2
80	*Cursorius cursor cursor*	+					1
81	*Glareola nordmanni*				+	+	2
82	*Glareola pratincola pratincola*	+	+		+	+	4
83	*Charadrius alexandrinus alexandrinus*	+	+		+	+	4
84	*Charadrius dubius curonicus*	+	+		+	+	4
85	*Charadrius hiaticula tundrae*		+	+	+	+	4
86	*Charadrius leschenaultii*	+	+		+	+	4
87	*Chettusia leucura*				+	+	2
88	*Eudromias morinellus*		+				1
89	*Hopolopterus spinosus*	+					1
90	*Pluvialis squatarola squatarola*		+	+	+	+	4
91	*Pluvialis squatarola squatarola*		+	+	+	+	4
92	*Vanellus vanellus*		+		+	+	3
93	*Actitis hypolecucos*		+		+	+	3
94	*Arenaria interpres interpres*		+		+	+	3
95	*Calidris alba*		+		+	+	3
96	*Calidris alpina alpina*		+		+	+	3
97	*Calidris canutus canutus*		+	+	+	+	4
98	*Calidris ferruginea*		+		+	+	3
99	*Calidris minuta*		+	+	+		4

No.	Scientific name	Resident	Visitor		Passer		Total
			W	Sp	Su	Au	
100	*Calidris temminckii*		+		+		3
101	*Gallinago gallinago gallinago*		+		+		3
102	*Gallinago media*		+		+		3
103	*Limicola falcinellus falcinellus*		+		+		3
104	*Limosa lapponica lapponica*		+		+		3
105	*Limosa limosa limosa*		+	+	+		4
106	*Lymnocryptes minimus*		+		+		3
107	*Numenius arquata arquata*		+	+	+		4
108	*Numenius phaeopus phaeopus*		+	+	+		4
109	*Numenius tenuirostris*		+		+		3
110	*Philomachus pugnax*		+	+	+		4
111	*Tringa erythropus*		+		+		3
112	*Tringa glarcola*		+	+	+		4
113	*Tringa nebularia*		+	+	+		4
114	*Tringa ochropus*		+	+	+		4
115	*Tringa stagnatilis*		+		+		3
116	*Tringa tonatus tonatus*		+	+	+		4
117	*Xenus cinereus*				+		2
118	*Phalaropus fulicarius*		+		+		3
119	*Phalaropus lobatus*				+		2
120	*Stercorarius longicaudus*				+		2
121	*Stercorarius parasiticus*		+	+	+		4
122	*Stercorarius pomarinus*		+	+	+		4
123	*Chlidonias hybrida hybrida*		+	+	+		4
124	*Chlidonias leucoptera*		+		+		3
125	*Chlidonias niger niger*		+	+	+		4
126	*Gelochelidon nilotica nilotica*		+		+		3
127	*Larus audouinii*				+		2
128	*Larus argentatus cachinnans*	+	+	+			3
129	*Larus canus canus*		+				1
130	*Larus foscus foscus*		+	+	+		4
131	*Larus genei*	+	+	+	+		5
132	*Larus hemprichii*	+	+				2
133	*Larus ichthyaetus*		+		+		3
134	*Larus melanocephalus*		+	+			2
135	*Larus minutus*		+				1
136	*Larus ridibundus*		+	+	+		4
137	*Rissa tridactyla tridactyla*		+				1
138	*Sterna albiforns albiforns*	+					1
139	*Sterna bengalensis par*	+			+	+	3
140	*Sterna caspia caspia*	+	+		+	+	4
141	*Sterna hirundo hirundo*			+	+	+	3
142	*Sterna sandvicensis sandvicensis*		+	+	+	+	4
143	*Pterocles senegallus*	+					1
144	*Columba oenas oenas*		+				1
145	*Streptopelai turtur arenicola*				+	+	2
146	*Streptopelia decaoclo decaoclo*	+					4
147	*Streptopelia senegalensis aegyptiaca*	+					1
148	*Streptopelia senegalensis senegalensis*	+					1
149	*Clamator glandarius*			+			1
150	*Cuculus canorus*				+	+	2
151	*Asio flammeus flammeus*		+		+	+	3

No.	Scientific name	Resident	Visitor		Passer		Total
			W	Sp	Su	Au	
152	*Asio otus otus*		+				1
153	*Athene noctua saharae*	+					1
154	*Otus scops scops*				+	+	2
155	*Caprimulgus europaeus meridionalis*				+	+	2
156	*Apus apus apus*				+	+	2
157	*Coracias garrulus garrulus*				+	+	2
158	*Alcedo atthis atthis*	+	+		+	+	4
159	*Halcyon smyrnensis smyrenensis*		+				1
160	*Merops apiaster*			+	+	+	3
161	*Upupa epops epops*	+			+	+	3
162	*Jynx torquilla torquilla*		+		+	+	3
163	*Delichon urbica urbica*		+	+	+	+	4
164	*Hirundo daurica rufula*	+	+	+			3
165	*Hirundo rustica savignii*	+					1
166	*Ptyonoprogne rupestris rupestris*		+				1
167	*Riparia riparia shelleyi*			+			1
168	*Alaemon alaudipes alaudipes*	+					1
169	*Alauda arvensis cantarella*		+				1
170	*Ammomanes cincturus arenicolor*	+					1
171	*Calandrella cinerea brachydactyla*	+	+		+	+	4
172	*Galerida cristata maculata*	+					1
173	*Anthus campestris campestris*		+		+	+	3
174	*Anthus cervinus*		+		+	+	3
175	*Anthus pratensis pratensis*		+				1
176	*Anthus spinoletta coutellii*		+		+	+	3
177	*Anthus trivialis*				+	+	2
178	*Motaacilla alba alba*		+		+	+	3
179	*Motacilla cinerea cinarea*		+		+	+	3
180	*Motacilla flava pygmaea*	+					1
181	*Lanius collurio collurio*		+		+	+	2
182	*Lanius excubitor elegans*	+					1
183	*Lanius minor minor*				+	+	2
184	*Lanius nubicus*				+	+	2
185	*Lanius senator senator*				+	+	2
186	*Oriolus oriolus oriolus*				+	+	2
187	*Corvus corone cornix*	+					1
188	*Corvus ruficollis ruficollis*	+					1
189	*Acrocephalus arundinaceus arundinaceus*				+	+	2
190	*Acrocephalus palustris*				+	+	2
191	*Acrocephalus schoenobaenus*		+		+	+	3
192	*Acrocephalus scripaceus fusca*	+	+				2
193	*Acrocephatus melanopogon melanopogon*				+	+	2
194	*Cercotrichas galactotes galactotes*						
195	*Cettia cettia orientalis*		+				1
196	*Hippolais olivetorum*				+	+	2
197	*Hippolais pallida elaeica*			+			1
198	*Locustella fluviatilis*				+	+	2
199	*Locustella luscinioides luscinoides*		+		+	+	3
200	*Phylloscopus bonelli bonelli*			+	+	+	3
201	*Phylloscopus collybita collybita*				+	+	2
202	*Phylloscopus sibilatrix*				+	+	2
203	*Phylloscopus trochilus trochilus*				+	+	2

No.	Scientific name	Resident	Visitor W	Sp	Passer Su	Au	Total
204	*Prinia gracilis gracilis*	+				+	2
205	*Prinia gracilis palestine*	+					1
206	*Sylvia atricapilla atricapilla*				+	+	2
207	*Sylvia borin borin*				+	+	2
208	*Sylvia cantillans albistriata*				+	+	2
209	*Sylvia communis communis*				+	+	2
210	*Sylvia conspicillata conspicillata*		+				1
211	*Sylvia curruca curruca*				+	+	2
212	*Sylvia melanocephala melanocephala*		+		+	+	3
213	*Sylvia nisoria nisoria*				+	+	2
214	*Sylvia ruppelli ruppelli*		+		+	+	3
215	*Ficedula albicollis*				+	+	2
216	*Ficedula semitorquata*				+	+	2
217	*Ficedula hypoleuca hypoleuca*				+	+	2
218	*Ficedula prava prava*		+		+	+	3
219	*Muscicapa striata striata*		+		+	+	3
220	*Luscinia luscinia*				+	+	2
221	*Luscinia megarhynchos megarhynchos*				+	+	2
222	*Luscinia svecica svecica*		+		+	+	3
223	*Monticola saxatilis saxatilis*		+		+	+	3
224	*Monticola solitarius solitarius*	+	+		+	+	4
225	*Oenanthe oenanthe oenanthe*		+		+	+	3
225	*Oenanthe deserti homachroa*	+					1
226	*Oenanthe hispanica melanoleuca*		+		+	+	3
227	*Oenanthe isabellina*		+		+	+	3
228	*Oenanthe lugens halophila*	+					1
230	*Phoenicurus phoenicurus phoenicurus*	+					1
231	*Saxicola rubetra rubetra*				+	+	2
232	*Saxicola torquata rubicola*		+		+	+	3
233	*Turdus merula merula*	+	+				2
234	*Turdus philomelos philomelos*		+				1
235	*Passer domesticus niloticus*	+					1
236	*Passer hispaniolensis hispaniolensis*		+	+	+	+	4
237	*Carduelis chloris aurantiiventris*	+	+				2
238	*Carduelis carduelis niediecki*		+				1
239	*Emberiza caesia*				+	+	2
240	*Emberiza calandra calandra*		+		+	+	3
241	*Emberiza hortulana*		+		+	+	3
242	*Emberiza melanocephala*				+	+	2
Total		67	154	47	171	170	

Autumn migration begins as early as mid- July at Zaranik, reaches a peak during the first two weeks of September and is nearly finished by the first week of November (Varty 1990). Studies carried out at Zaranik and along the North Sinai and Palestine coast have shown that there are two separated migration routes across this area in autumn (Paran & Paz 1978). Most waterbirds (herons, duck waders, kingfishers) and harriers travel in a westerly direction following the coastline from Palestine. Because of the curvature of the coastline this stream naturally concentrates at Zaranik, but thereafter spreads out over

Sinai, heading south or southwest on across the Red Sea or continuing westward towards the Nile Delta and Valley. Most passerines, several other raptor species (harriers, osprey and falcons), rails, quail (*Coturnix coturnix)*, hoopoe (*Upupa epops),* roller (*Coracias garrulus)* and bee-eater (*Merops apiaster)* migrate in a southerly direction flying directly across the Mediterranean from Cyprus, Turkey and Greece and do not show such a concentrations of numbers at Zaranik.

The main raptor migration routes are further to the east (Porter & Beaman 1985) and a few birds fly directly along the coast of north Sinai, as shown by the generally low numbers of birds of prey in the counts of Zaranik. Harriers and falcons are the commonest birds of prey recorded at Zaranik in the autumn, where they are most frequently observed migrating birds along the coastal scrub belt just south of the shoreline in a westerly direction, or coming from the north across the Mediterranean. These birds are active migrators (they do not depend largely on thermals to keep aloft), and migrate on a broad front. Consequently they are likely to be under-recorded and are probably more common in the area than the records show.

12.3.2 Winter

Few ornithologists have visited Zaranik Protected Area in winter and data on the bird populations during this season are scant. The International Wetlands Research Bureau (IWRB) in collabration with Foundation for Ornithological Research in Egypt (FORE) and Egyptian Wildlife Service (EWS) conducted a two-day survey of the avifauna of the Zaranik Lagoon during 11 and 12 January 1990. They recorded 31 species including 1,700 greater flamingo (*Phoenicopterus ruber*) and 370 kentish plover, but relatively small number of other species. The majority of these greater flamingos are thought to breed in Iran and Turkey (see Tharwat & Hamied 2000).

Table 12.4. **National and world distribution of the bird species recorded in Lake Bardawil (after Goodman *et al.* 1989, Tharwat 1997).**

No.	Scientific name	World distribution	National distributiom
1	*Calonectris diomedea diomedea*	Mediterranean waters and Atlantic Ocean	Mediterranean and Red Seas
2	*Puffinus griseus*	N. Atlantic, North to Iceland, N Sea, English Channel	Mediterranean and Red Seas
3	*Puffinus puffinus yelkouan*	Coastal regions & Atlantic Islands, Mediterranean & Pacific areas	Mediterranean and Red Seas
4	*Podiceps cristatus cristatus*	Parts of Europe, Asia, Africa, Australia	Nile Valley and Delta, Suez Canal, Aqaba Gulf.
5	*Podiceps nigricollis nigricollis*	Atlantic Coasts, Medet. Region, Arabic Gulf.	Nile Delta and Valley, Suez Canal, Lake Bardaweel, other Coastal Waters.
6	*Tachybaptus ruficollis ruficollis*	Europe, Asia, Africa.	Nile Valley and Delta, W. Desert Oases.
7	*Phalacrocorax carbo sinensis*	Europe, C. and S. Asia, Africa, Australia and E.N. America.	Nile Delta and Valley, Red Sea, Medit. Sea.
8	*Sula bassana bassana*	Europe, N. America, W. coast of Africa	Mediterranean Sea coast
9	*Pelecanus onocrotalus*	S. Europe & Asia & Africa	Sinai, S. Nile Delta and Valley,

No.	Scientific name	World distribution	National distributiom
			Delta wetland, Suez Canal
10	*Ardea cinerea cinerea*	Europe, Asia & Africa	Nile Delta and Valley, Red Sea, Medit. Sea.
11	*Ardea goliath*	Sengal to Sudan, Cape Province, Gulf Aqaba, Oman	Red Sea, S. Nile Valley
12	*Ardea purpurea purpurea*	Europe, Asia, Africa	Nile Valley & Delta
13	*Ardeola ralloides*	S. Europe, S.W. Asia & Africa	Bilbais, Aswan, Damietta
14	*Botaurus stellaris stellaris*	C. & S. Europe, N.W. & S. Africa, C. & W. Asia	Nile Delta
15	*Egretta alba alba*	S. Europe, N. Asia, N. Africa, India.	Nile Delta and Valley.
16	*Egretta garzetta garzetta*	Europe, S. Asia, Africa, Australia	Nile Delta and Valley, Mediterranean coast
17	*Egretta ibis ibis*	Spain to Iran, N. and C. Africa, E.N. and N.S. America.	Nile Delta and Valley.
18	*Ixobruchus minutus minutus*	Europe, Asia, Africa, Australia.	Nile Delta and Valley.
19	*Nycticorax nycticorax nycticorax*	C. and S. Europe, S. Asia, Africa	Bilbais, Aswan
20	*Ciconia ciconia ciconia*	C. & E. Europe, Spain, Turkey, Asia Minor, C. & E. Asia, N.W. Africa, S. Africa	Sinai, N. Red Sea, S. Nile Valley
21	*Ciconia nigra*	Europe, Africa, Asia	Red Sea & Nile Valley
22	*Plegadis falcinellus*	S. Europe, S. Asia, E. Africa, N. America, Australia	Nile Valley & delta
23	*Platalca lcucordia lcucordia*	Europe, S. Asia & Africa	Red Sea
24	*Phoenicopterus ruber roseus*	Africa, S. Asia, C. America, S. Europe	Mallaha, Bardawil & Qarun Lakes
25	*Anas acuta acuta*	Eurasia, America, Africa	Nile Valley & Delta
26	*Anas angustirostris*	Europe, N.W. Africa, S. Turkey, S.W. Iraq & Iran, E & C. Arabia, Vagrant Cyprus, Oman	Wadi El-Natrun, Lake Qarun, Dakhla Oasis, M. Nile Valley, E. Delta
27	*Anas clypeata*	Medit. Basin, W. Morocco, E. Africa, Iran, Iraqi.	Nile Delta and Valley.
28	*Anas crecca crecca*	Europe, Asia, Africa, N. America	Nile Delta and Valley
29	*Anas penelope*	Europe, Asia, Africa, N. America.	Nile Delta and Valley.
30	*Anas platyrhynchos platyrhynchos*	Europe, Asia, N.W. Africa, N. America.	Nile Delta and Valley.
31	*Anas querquedula*	Europe, Asia, Africa	Mediterranean, Red Sea.
32	*Anas strepera strepera*	N. Hemisphere throughout to China and Japan, to the W. Indies, Mexico, Florida.	Nile Delta and Valley.
33	*Aythya ferina*	Europe and Asia.	Nile Delta and Valley.
34	*Aythya fuligula*	Europe, Asia, Africa.	Nile Delta and Valley.
35	*Aythya nyroca*	Europe and Asia to Lake Baikal, in non-breeding season to Cape Verde Islands, Iran, N Africa, Sudan, S. Arabia, India, China.	Nile Delta and Valley.
36	*Mergus serrator serrator*	Europe, Africa	Suez Canal, Lake Bardawil, Suez Gulf, Aqaba Gulf
37	*Netta rufina*	Europe, Turkey, Near East., Iraq, Marocco, Algeria, E. and C. Arabia, Tunisia, Libya.	Nile Delta and Valley.
38	*Tadorna tadorna*	Europe, Asia.	Medit. Sea, N. Red Sea.
39	*Accipiter nisus nisus*	Europe, Palaearctic Asia, N.W. Africa	Nile Delta & Valley
40	*Accipiter brevipes*	Balkans to S. Russia, Egypt	Eastern Desert, Sinai
41	*Aquila heliaca heliaca*	Greece to Siberia, N.E. Africa, India	Sinai
42	*Aquila nipalensis orientalis*		
43	*Aquila pomarina pomarina*	C. & E. Europe	N. Eastern Desert, Sinai
44	*Buteo buteo vulpinus*	Europe, C & N. Asia	Nile Delta & Valley
46	*Buteo rufinus rufinus*	C. Europe to C. asia	Nile Delta & Valley

No.	Scientific name	World distribution	National distributiom
47	*Circaetus gallicus gallicus*	C. & S. Europe, N.E. Africa, C. & S. Asia	Mukattam Hills, Wadi El-Natrun
48	*Circus aeruginosus aeruginosus*	Europe, Asia, Africa.	Nile Delta and Valley.
49	*Circus cyaneus cyaneus*	Europe, Asia, N. Africa.	Nile Delta.
50	*Circus macrourus*	E. Europe, C. Asia to Africa, India	Eastern parts of country
51	*Circus pygargus*	W. Europe, E. C. Asia, China	Wide spread
52	*Gyps fulvus fulvus*	S.E. Europe, N. Africa to C. Asia	Sinai, Eastern Desert
53	*Hieraaetus pennatus pennatus*	S. Europe to N. Africa, Caucasus	Eastern Desert, Sinai
54	*Milvus migrans migrans*	Europe, Asia, N.W. Africa	Nile Delta & Valley, Cairo
55	*Neophron percnopterus percnopterus*	S. Europe, Middle East, Africa	S. Sinai, Eastern Desert, Nile Valley, Gabal Elba, Lake Nasser
56	*Pernis apivorus apivorus*	Europe, N. Asia & Africa	Sinai & Red Sea mountains
57	*Pandion haliaetus haliaetus*	Europe, Asia, S. Africa, India, S. Island	Red Sea coast, Lake Nasser, S. Nile Valley
58	*Falco biarmicus tanypterus*	N. Africa, Arabia, Iraq	Eastern & Western Deserts, Sinai
59	*Falco cherrug cherrug*	C. Asia, N.W. Monogolia to N. Africa, N. India	Sinai, Eastern Desert
60	*Falco columbarius aesalon*	Europe to N. Russia, W. Siberia	Nile Delta
61	*Falco concolor*	---	Red Sea Islands, Sinai, Eastern & Western Deserts
62	*Falco eleonorae*	Canary Island, Mediterranean Islands, Madagascar	Eastern parts of country
63	*Falco naumanni naumanni*	S. Europe to China, S. Africa	Alexandria, Deversoir, Suez
64	*Falco peregrinus peregrinus*	Worldwide	Mountains, Coasts, Marshes
65	*Falco subbuteo subbuteo*	Europe to Japan, N. Africa, India	N.E. Sinai
66	*Falco tinnunculus tinnunculus*	Europe, to N.E. Asia C. Africa, India.	Nile Delta and Valley, Sinai, N. Coast.
67	*Falco vespertinus vespertinus*	C. Europe to C. Asia, W & S.W. Africa	Eastern parts of country
68	*Coturnix coturnix coturnix*	Europe, W. Asia to C. Africa, India	Nille Valley & Delta
69	*Grus grus grus*	N. & E. Europe, W. Russia, N.E. Africa	Nille Valley & Delta, E. Egypt, Western Desert
70	*Crex crex*	Europe, N. Africa to C. Asia	N. Coast of Sinai
71	*Ardeola ralloides*	S. Europe, S.E. Asia, Africa.	Bilbais, Aswan, Damietta
72	*Gallinula chloropus chloropus*	Europe, N. Africa, Meddle East, Russia	Nile Delta and Valley, Suez Canal, Faiyuum
73	*Porzana prava*	W. Europe, N. Africa to C. Asia, India	Sinai, S. Nile Valley, Wadi El-Natruun, W. Desert
74	*Rallus aquaticus aquaticus*	W. Europe to W. Siberia, N.E. Africa.	N. Egypt.
75	*Ardea cinerea cinerea*	Europe, Asia, Parts of Africa.	Nile Delta and Valley, Red and Medit. Seas.
76	*Haematopus ostralegus ostralegus*	Europe, Asia Minor, N. Africa	Mediterranean & Red Seas
77	*Himantopus himantopus himantopus*	S. Europe to China, India, C. Africa.	Wadi El-Natruun, Faiyuum, N. Nile Delta
78	*Phoenicopterus ruber roseus*	Africa, S.W. Asia, C. America, S. Europe.	Lake Mallaha, Lake Bardaweel, Lake Qaruun
79	*Burhinus oedicnemus oedicnemus*	Europe, S.W. Asia to N. & E. Africa	N. Coast, Western & Eastern Deserts, Nille Valley & Delta
80	*Cursorius cursor cursor*	N. Africa to N.W. India	Desert areas
81	*Glareola nordmanni*	S.E. Europe, C. Asia, Africa	Eastern parts of Egypt
82	*Glareola pratincola pratincola*	Medit. to N.W. India India, N. Africa.	Nile Delta, W. N. Coast
83	*Charadrius alexandrinus alexandrinus*	E. Asia, Red Sea, S. Africa, Australia.	Medit. and Red Seas Coasts.
84	*Charadrius dubius curonicus*	Europe, N. Asia, S. Africa, India, China	Wadi El-Natruun, W. Oases, North coast, Nile Delta, Red Sea coast,

No.	Scientific name	World distribution	National distributiom
			Sinai
85	*Charadrius hiaticula tundrae*	N. Europe, N. Asia, Iran, E. Africa.	W. Desert, Nile Delta and Valley, Red Sea.
86	*Charadrius leschenaultii*	C. Asia, India, Malaysia, E. Africa.	Red Sea.
87	*Chettusia leucura*	W. and C. Asia, N.E. Africa, N.W. India.	E. Egypt.
88	*Eudromias morinellus*	N. Europe, N. Asia, Mediterranean, Iran	North of the country
89	*Hopolopterus spinosus*	Middle East, C. and E. Africa.	Wadi El-Natruun, Nile Delta and Valley, Suez Canal, Faiyuum, Sinai, Wadi El-Rayan
90	*Pluvialis squatarola squatarola*	Circumpolar, Africa, Australia, S. America, Europe	N. Egypt, Red Sea.
91	*Pluvialis apricaria apricaria*	N.E. Europe, N. Asia, Mediterranean, N. India	Nile Delta, N. & W. Sinai
92	*Vanellus vanellus*	W. Europe to China, Japan.	N. Egypt.
93	*Actitis hypoleucos*	Palaearctic, Africa, N.E. Asia to Australia.	Nile Delta and Valley, W. Desert Oases, Red Sea Coast
94	*Arenaria interpres interpres*	N. Palaearctic, Africa, S.E. Asia, Australia.	Medit.and Red Sea Coasts, Suez Canal.
95	*Calidris alba*	N. Holarctic, S. America, India, Australia.	Medit. and Red Sea Coasts, Inland Waters.
96	*Calidris alpina alpina*	N. Europe, N.W. Asia, S.W. Asia, N.E. Africa.	Faiyuum, Nile Delta lakes, Red Sea Coast, W. Desert
97	*Calidris canutus canutus*	Taimyr Peninsula, Africa	Suez, Bilbes, Faiyum
98	*Calidris ferruginea*	N. Asia to Europe, Africa, India, Australia.	Mediterranean Coast, Nile Delta, Lake Qaruun, Suez.
99	*Calidris minuta*	N. Europe, S. Africa, W. India.	N. lakes
100	*Calidris temminckii*	N. Europe, N. Asia, N.E. Africa to China.	Deversoir, Red Sea Coast.
101	*Gallinula chloropus chloropus*	Europe, N. Africa, Middle East., Russia.	Nile Delta and Valley, Suez Canal, Faiyuum.
102	*Gallinago media*	N. Europe, W. Asia, E. Africa	Nile Delta, Wadi El-Natrun
103	*Limicola falcinellus falcinellus*	N. Europe, N. Russia, Middle East, W. India	N. Sinai, Suez, Nile Delta
104	*Limosa lapponica lapponica*	N. Europe, N. Asia, Tropical Africa, N. India	Mediterranean and Red Sea coasts
105	*Limosa limosa limosa*	Europe, W. Asia, N. Africa, India.	N. Sinai, Wadi El-Natruun, Faiyuum, Nile Delta, Red Sea
106	*Lymnocryptes minimus*	N. Europe, W. Asia, N. Africa, Iran, India	Western Desert, Oases, Nile Delta, Suez Canal, Faiyuum, N. Sinai.
107	*Numenius arquata arquata*	N. Europe, Russia, Africa, N.W. India.	Coastal Areas, Inland lakes, Red Sea Coast.
108	*Numenius phacopus phacopus*	Ethiopia, N. Asia, Africa, N.W. India	Sinai, N. coast, Red Sea area
109	*Numenius tenuirostris*	S.W. siberia to E. Europe, Iran	Alexandria, Faiyum, N. Sinai coast
110	*Philomachus pugnax*	N. Europe, Asia, Africa, India, Burma	Nile Delta and Valley
111	*Tringa erythropus*	N. Europe, N. Russia, Africa, China.	Lake Maryut, W. Desert Oases, Red Sea Coast, Nile Delta and Valley.
112	*Tringa glareola*	N. Palaearctic, Africa, S.E. Asia, Australia.	W. Desert, Red Sea Coast, Mountains of S. Sinai
113	*Tringa nebularia*	N. Palaearctic, Africa, India to New Zealand.	W. Desert Oases, Nile Delta and Valley, Red Sea Coast
114	*Tringa ochropus*	N. Palaearctic, C. Africa to Philippine Islands.	N. Coast of Sinai, Bahariya Oasis.
115	*Tringa stagnatilis*	S. Europe to Mangolia, Africa, Australia	W. Desert Oases, Nile Valley, Red Sea Coast
116	*Tringa tonatus tonatus*	N. Europe, W. Siberia, Africa, W. Asia.	Lake Manzala, Suez Bay, W. Desert and Nile Valley.
117	*Xenus cinereus*	N.E. Europe, W. Siberia, E. Africa, India, Australia	Red Sea coast, N.W. coast

No.	Scientific name	World distribution	National distributiom
118	*Phalaropus lobatus*	N. America, N. Palaearctic, southern coasts	Aswan, Lake Nasser, Lake Maruit
119	*Phalaropus fulicarius*	N. Holarctic, Coasts of Africa , Chile	Nile Delta, N. Sinai coast
120	*Stercorarius longicaudus*	N. Holarctic, S. South America, W. Africa, Mediterranean, Japan	N. Sinai coast, N. Red sea
121	*Stercorarius parasiticus*	N. Holarctic, S. South America, S. Africa, India, Australia	N. Sinai coast, Suez Canal, Red Sea
122	*Stercorarius pomarinus*	N. Holarctic, Peru, S. Africa, India, N. Australia	N. Sinai coast, Lake Bardawil, Red Sea
123	*Chlidonias hybrida hybrida*	S. Europe, S.W. Asia, E. and W. Africa.	Nile Delta
124	*Chlidonias leucoptera*	Europe, W. Asia, S.C. Africa.	Wadi El-Natrun, N. Sinai, Nile Delta & Valley, Red Sea Coast
125	*Chlidonias niger niger*	Europe, W. Asia, S.C. Africa.	Wadi El-Natruun, N. Sinai, Nile Delta and Valley, Red Sea.
126	*Gelochelidon nilotica nilotica*	Europe, C. Asia, N & E. Africa, India	Nile Delta & Valley
127	*Larus audouinii*	Mediterranean islands	Lake Manzala, Lake Qarun
128	*Larus cachinnans cachinnans*	S. Russia, S.C. Asia, N. Red Sea	W. Mediterranean coast
129	*Larus canus canus*	N.W. Europe to Medierranean	N. Egypt, mainly Nile Delta, Red Sea.
130	*Larus fuscus fuscus*	Scandinavia to W. and E. Africa.	Nile Valley, Suez Canal, Red Sea, N. Sinai, Wadi El-Natruun, Lake Qaruun.
131	*Larus genei*	Medit. Sea, Black Sea, Asia Minor.	N.W. Sinai, Lake Qaruun, Medit. and Red Seas.
132	*Larus hemprichii*	S. Red Sea, Iran, E. Africa coast	Red Sea Islands, N. Red Sea
132	*Larus hemprichii*		
133	*Larus ichthyaetus*	S. Russia, Mongolia to Red Sea, India.	Red Sea Coast, Nile Delta and Valley.
134	*Larus melanocephalus*	S.E. Europe, C. & W. Africa	Mediterranean coast, Nile Delta
135	*Larus minutus*	N. Europe, Siberia to Medit., Black Sea.	Medit. and Coast, Nile Delta and Valley, Red Sea, S. Sinai
136	*Larus ridibundus*	Europe, Asia to N. Africa, India, Philippine Islands.	Nile Delta and Valley, Red Sea Coast, Lake Qaruun, Lake Nasser
137	*Rissa tridactyla tridactyla*	N.E. Canada, N.W. Europe to Azores, USA	Northern parts of country
138	*Sterna albiforns albiforns*	Europe, W. Asia, N. Africa, N.E. India.	Medit. and Red Sea Coasts, Faiyum.
139	*Sterna bengalensis par*	N. Africa, Madagascar	Red Sea Islands, Mediterranean coast, Nile Delta, Suez Canal
140	*Sterna caspia caspia*	N. America, Europe, Africa, C. & S. Asia	Red Sea coast, Mediterranean coast, Nile Delta
141	*Sterna hirundo hirundo*	N. America, Europe, W. Asia, S. America, W. Africa	Mediterranean and Red Sea coasts, Nile Valley, Suez Gulf.
142	*Thalasseus sandvicensis sandvicensis*	W.S. Europe, Africa, N.W. India.	Coasts of Medit, Red Seas.
143	*Pterocles senegallus*	N.E. Africa, Middle East, India	Nile Delta & Valley, Eastern Desert, Sinai
144	*Columba oenas oenas*	Europe, N. Africa, Asia Minor	Wadi El-Natrun, Nile Valley & Delta, Sinai
145	*Streptopeliaturtur arenicola*	N. Africa, S.W. Asia	Nile Delta & Valley
146	*Streptopelia decaoclo decaoclo*	Europe to W. China	Wadi En-Natruun, Nile Delta, N. Nile Valley, Suez Canal, Sinai
147	*Streptopelia senegalensis aegyptiaca*	Endemic.	Nile Delta and Valley, E. and W.E. Deserts.
148	*Streptopelia senegalensis senegalensis*	Sengal to Ethiopia, Cape Province	Gabael Elba, Upper Egypt
149	*Clamator glandarius*	Spain to Iran, N.E. & S. Africa	Nile Valley
150	*Cuculus canorus canorus*	Europe, W. Siberia, E. and S. Africa	Western Desert, Eastern Desert,

No.	Scientific name	World distribution	National distributiom
			Sinai
151	*Asio flammeus flammeus*	Europe, N. Asia, N. Africa, N. America	North coast, Western Desert, Nile Valley & Delta, Sinai, Red Sea
152	*Asio otus otus*	Europe, Asia, N.W. Africa	Nile Delta
153	*Athene noctua glaux*	N. Africa	N. Coast, Nile Delta and Valley
154	*Otus scops scops*	W. Europe to Russia, C. Africa	Western Desert, Nile Delta & Valley, Red Sea, Sinai
155	*Caprimulgus europaeus meridionalis*	S. Europe, N. & W Africa, Caucasus	Mediterranean coast, Nile Delta, Western Desert, Suez Canal
156	*Apus apus apus*	W. Europe to C. Asia & Africa	Western Desert, Nile Valley & Delta
157	*Coracias garrulus garrulus*	S. Europe to C. Asia & Africa, India	Western & Eastern Deserts, North coasts
158	*Alcedo atthis atthis*	Mediterranean, Syria, Arabia.	N. coast. Western Desert, Nile Delta and Valley, Suez canal
159	*Halcyon smyrnensis smyrenensis*	Asia Minor to S. Yemen, India	Nile Delta, N. Sinai coast
160	*Merops opiaster*	S. Europe, C. Asia, N. India & Africa	Western Desert, Eastern Desert, N. Sinai, Nile Delta and Valley
161	*Upupa epops epops*	Europe, W. Asia to W. and C. Africa, India.	Nile Delta and Valley, W. Oases, N. Sinai, Suez Canal.
162	*Jynx torquilla torquilla*	Europe, W. Asia	Desert areas, Nile Valley & Delta, Sinai
163	*Delichon urbica urbica*	S.E. Africa	S. Sinai, N. Sinai, Red Sea
164	*Hirundo daurica rufula*	S. Europe, Iran, Afghanistan, N.E. India	N. coasts, Faiyum, Delta lakes
165	*Hirundo rustica savignii*	--	Nile Valley & Delta, Suez Canal, Faiyum
166	*Ptyonoprogne rupestris rupestris*	S. Europe, C. & W. Asia, N.E. Africa, India	Northern parts of country
167	*Riparia riparia shelleyi*	Sudan, Egypt	Nile Valley & Delta, Suez Canal, Faiyum, Wadi El-Natrun
167	*Riparia riparia riparia*	N. America, N. S. America, Europe, Asia, N. and N.E. Africa	Desert areas, Nile Delta and Valley
168	*Alaemon alaudipes alaudipes*	N. Africa, Sahara	Mediterranean coast, Qattara depression, Western Desert, Nile Valley & Delta
169	*Alauda arvensis cantarella*	S.E. Europe, Iran, N.E. Africa	Northern parts of country, Suez Canal, N. Sinai
170	*Ammomanes cincturus arenicolor*	N. Africa, Sinai, Arabia	N. coasts, Nile Valley & Delta, Red Sea, Nile Valley & Delta,, Deserts
171	*Calandrella cinerea brachydactyla*	S. Europe, Rosetta, N. Africa	N. Egypt, Western Desert
172	*Galerida cristata maculata*	E. Moracco, C. Algeria, S. Tunisia, Libya	N.W. coast
173	*Anthus campestris campestris*	Europe, N. Africa, Iran, Arabia, S.E. Asia	Nile Valley & Delta, S. Sinai, Faiyum
174	*Anthus trivialis*	Europe, Asia, Africa, India	Suez area, S. Sinai
175	*Anthus pratensis pratensis*	Greenland, Europe, N. Africa, Iran, Asia Minor	Nile Delta, Faiyum, Wadi El-Natrun, Suez Canal, S. Sinai
176	*Anthus spinoletta coutellii*	C. Asia, Tibet, China, N. India, Iran	Western Desert, Red Sea coast, Aswan
177	*Anthus trivialis*	Europe, Asia, Africa, India	Suez area, S. Sinai
178	*Motacilla alba alba*	Europe, Russia, N. and E. Africa, Iran, Arabia.	Nile Delta and Valley, E. Desert, N. Coast
179	*Motacilla cincrca cinarca*	Europe, N. Africa, Iran, India, C. S. Africa	N. Sinai coast, N. coast, W. desert, Nile Delta and Valley, Suez Canal, Faiyuum.
180	*Motacilla flava flavissima*	Northwest Europe, Spain, N. Africa	S. Sinai, Gabal Elba, Gabal Uweinat, Suez Canal, Upper

No.	Scientific name	World distribution	National distributiom
			Egypt.
181	*Lanius collurio collurio*	Europe, Siberia, W. Asia, S. Africa	N. coast, W. Desert, W. Nile Delta
182	*Lanius excubitor elegans*	Sahara, S. Egypt	N. coast, Nile Valley & Delta, N. Eastern Desert, Suez Canal, Sinai
183	*Lanius minor minor*	S.& E. Europe, E. & S. Africa	Nile Valley & Delta, S. Sinai, Faiyum
184	*Lanius nubicus*	S. Europe to Iraq, N.E. Africa	Nile Valley & E. Delta, Western Desert
185	*Lanius senator senator*	Europe, N. Africa	Deserts, Sinai, throughout the country
186	*Oriolus oriolus oriolus*	Europe, W. & W.C. Asia, E. & S. Africa, N.W. India	S.E. Alexandria
187	*Corvus corone cornix*	N. E. Europe.	Nile Delta and Valley, Suez Canal, Fayiuum, N.E. Sinai
187	*Corvus corone cornix*	N. & E. Europe	Nile Valley & Delta, N.E. Sinai, Faiyum, Suez Canal
188	*Corvus ruficollis ruficollis*	N. Africa to Pakistan	Most desert areas
189	*Acrocephalus arundinaceus arundinaceus*	Europe, Asia Minor, N.E. & W. & S.C. Africa	
190	*Acrocephalus palustris*	N. Europe, Russia, N.W. & S.E. Africa	Nile Valley & Delta
191	*Acrocephalus schoenobaenus*	Europe, W. & C. Asia, E.S. & S.E. Africa	Western & Eastern Deserts, Sinai
192	*Acrocephalus scripaceus fusca*	Asia Minor, C. Asia, E. Africa	Nile Delta, Red Sea
193	*Acrocephatus melanopogon melanopogon*	Europe, N. Africa	Sinai, Suez Canal
194	*Cercotrichas galactotes galactotes*	W. Mediterranean, N. Africa, S. Sahara	North coast, Nile Delta & Valley, Faiyum, Suez Canal
195	*Cettia cettia orientalis*	Middle East, N. Iran	Suez
196	*Hippolais olivetorum*	S.E. Europe, Asia Minor, N. africa	Upper Egypt, N. Sinai
197	*Hippolais pallida elaeica*	S.E. Europe, Iran, S.E. Asia, Ethiopia	N. Sinai
198	*Locustella fluviatilis*	N. Europe, N.E. Asia, N.E. Africa	Western Desert, N. Sinai
199	*Locustella luscinioides luscinioides*	C. & E. Europe, Iberia, N. Africa	Western Desert
200	*Phylloscopus bonelli bonelli*	S. Europe, N. Africa	Upper Egypt
201	*Phylloscopus collybita collybita*	W.C. Europe, N. Africa	Red Sea coast, Gebel Elba
202	*Phylloscopus sibilatrix*	W.C. & N.E. Europe, C. Africa	N. coast , Nile Valley & Delta, Western Desert, Faiyum
203	*Phylloscopus trochilus trochilus*	Britian, W. Europe, W. & C.W. Africa	Upper Egypt
204	*Prinia gracilis gracilis*	----	Nile Valley
205	*Prinia gracilis palestine*	N.E. Sudan, Somalia	Suez Canal, Nile Valley, Faiyum, Wadi El-Rayan
206	*Sylvia atricapilla atricapilla*	W. Europe, W. Russia, N. & E. Africa	Wadi El-Natrun, Nile Delta & Valley, N. Red Sea
207	*Sylvia borin borin*	Europe, W. Russia, W.C. Africa	Western Desert, Upper Nile Valley
208	*Sylvia cantillans albistriata*	S. Europe, Asia Minor, N.E. Africa	Red Sea, Giza
209	*Sylvia communis communis*	Europe, N., C. & S. Africa, Russia	
210	*Sylvia conspicillata conspicillata*	S. Europe, N. Africa	Eastern Desert, Sinai, Wadi El-Natrun, Nile Delta, N. coast
211	*Sylvia curruca curruca*	Europe, E. Russia, N. & C. Africa	Most of the country
212	*Sylvia melanocephala melanocephala*	S. Europe, N. Africa	Nile Valley, N. Sinai
213	*Sylvia nisoria nisoria*	C. & E. Europe, W. Russia, E. Africa	Western Desert, C. Sinai, Suez
214	*Sylvia ruppelli ruppelli*	S.E. Europe, N.E. Africa	Troughout the country
215	*Ficedula albicollis albicollis*	C. & E. Europe, S.C. Africa	Western Desert, C. Sinai

No.	Scientific name	World distribution	National distributiom
216	*Ficedula albicollis semitorquata*	C. & E. Europe, S.C. Africa	N. Sinai, Giza
217	*Ficedula hypoleuca hypoleuca*	N. Europe, W. Siberia, N.C. Africa	Western Desert, Suez Canal, W.-N. coast
218	*Ficedula prava prava*	C. & E. Europe, W. Himalayas, N. India	Western Desert, Wadi El-Natrun
219	*Muscicapa striata striata*	Europe, Asia Minor, S. Africa	Faiyum, Giza
220	*Luscinia luscinia*	Europe, W. Asia, S.C. Africa	N. Sinai, north coast, Upper Egypt
221	*Luscinia megarhynchos megarhynchos*	W. Europe, N., W., W. & C. Africa	Troughout the country
222	*Luscinia svecica svecica*	N. – E. Europe, N. Asia, India, China	North coast, Western Desert, Nile Delta & Valley, Faiyum, Suez Canal, Sinai, Red Sea coast
223	*Monticola saxatilis saxatilis*	C. & S. Europe to W. China, N. India, E. Africa	Gabel Uweinat, Western Desert, Faiyum
224	*Monticola solitarius solitarius*	S. Europe, Midle East, W. & C. africa	Sallum, Giza, Cairo, Nile Valley, Sinai, Eastern Desert
225	*Oenanthe deserti homachroa*	N. Africa	Western Desert, north coast
226	*Oenanthe hispanica melanoleuca*	E. Europe, Asia Minor, N.E. & W. Africa	S. & N. Sinai, Upper Egypt
227	*Oenanthe isabellina*	E. Europe, W. China, India, C. Africa	Troughout the country
228	*Oenanthe lugens halophila*	N. Africa	Mountains of Eastern Desert, Nile west banks, Sinai
229	*Oenanthe oenanthe oenanthe*	N. & C. Europe, N. Asia, C. Africa	Mediterranean coast, Wadi El-Natrun, N. Red Sea, Sinai, Gebel Elba, Upper Nile Valley
230	*Phoenicurus phoenicurus phoenicurus*	Europe, N. Africa, C. Asia, W. & E. Africa	Troughout the country
231	*Saxicola rubetra rubetra*	Europe, Asia, N.W. & C. Africa	N. Sinai
232	*Saxicola torquata rubicola*	W. Europe, N. Africa, Middle East.	Nile Delta and Valley, Suez Canal Area, Faiyuum, Wadi El-Natruun, E. Sinai.
233	*Turdus merula merula*	W. Europe	Nile Delta, N.E. Sinai
234	*Turdus philomelos philomelos*	C. Asia, S., C. & E. Europe, N. Africa	North coast, Western Desert, Nile Delta & Valley, Faiyum
235	*Passer domesticus niloticus*	N.E. Africa.	N. Coast, W. Desert, Nile Delta and Valley, Red Sea Coast, Sinai.
236	*Passer hispaniolensis hispaniolensis*	S.W. Europe, N. Africa Asia Minor.	N. Coast, Nile Delta and Valley, Faiyuum, Suez Canal and Sinai
237	*Carduelis chloris aurantiiventris*	S. Europe, N. Africa	Nile Delta, Suez Canal, N. Sinai
238	*Carduelis carduelis niediecki*	W. & C. Europe	Nile Delta & Valley, Western Desert Oases, N. Sinai
239	*Emberiza cacsia*	E. Europe, N.E. Africa, Sudan, Iran	Nile Delta & Valley
241	*Emberiza hortulana*	Europe, N. Africa, C. Asia, Senegal, Sudan, Iran	Suez Canal, Eastern Desert, Sinai
242	*Emberiza melanocephala*	S.E. Europe, Iran, Caucasus, N. & C. India	N. Sinai

12.3.3 Spring

Fry *et al.* (1985) recorded 139 bird species between 18 April and 3 May 1985 around EL Arish and Lake Bardawil (including Zaranik). A survey conducted on 30 April 1990 led to recording only 37 species (mainly at Zaranik), there were probably more than 1,300 greater flamingos present within this area at that time. From the available data, and the known migration patterns in other areas of Egypt, it seems that Zaranik does not have the overall importance for migrant waterbirds in spring as it does in autumn (there were no special concentrations of species at that time).

Fry *et al.* (1985) recorded large movements of raptors at El Arish in late April, involving 2,500 birds belonging to 23 species. However, it seems that Zaranik Protected Area is not a regular passage point for migratory raptors in spring. Such major soaring bird movement is strictly associated with warm south winds in spring time and consequently does not occur continuously. In the normal days of spring 1990, very little raptor migration was observed around the reserve.

12.3.4 Summer

There have been very few studies of the avifauna of the Zaranik Protected Area during the summer months, consequently little is known of the birds which breed there. According to Shariv (1970), Meininger & Mullie (1981) and Fry *et al.* (1985), confirmed breeding species around Lake Bardawil area include: kentish plover *(Charadrius alexandrinus alexandrinus)*, spur-winged plover (*Hoplopterus spinosus)*, little tern *(Sterna albifrons albifrons)*, palm dove *(Streptopelia senegalensis)*, collared dove *(Streptopelia decaocto)*, little owl *(Athene noctua)*, great grey shrike *(Lanius excubitor)*, crested lark *(Galerida cristatus)*, hoopoe lark *(Alaemon alaudipes)*, black-headed bulbul *(Pycnonotus barbatus)*, house sparrow *(Passer domesticus)*, avocet *(Recurvirostra avosetta)* and possible graceful warbler *(Prinia gracilis)*, desert wheatear *(Oenanthe deserti)* and greater sand plover *(Charadrius leschenaultii)*.

Atta (1988a) found colonies of little terns on several islands in Zaranik Lagoon and five avocet nests were discovered in salt pans at Zaranik in late May 1990 (see Tharwat & Hamied 2000) . Relatively few species were recorded by the field team who visited Zaranik in July 1990 and recorded kentish plover, avocet and little tern as confirmed breeding.

12.4 ORIGIN AND DESTINATION OF MIGRANT BIRDS AT ZARANIK

Many birds passing through the Zaranik Protected Area originate from the populations breeding over a large area of Eurasia and they winter across similarly huge areas of north and sub-Saharan Africa (Fig. 12.1). For instance, recoveries of ringed birds show that a significant part of the migrating Herons of Zaranik come from breeding grounds around the Avov Sea and Volga Delta (Kistchinski 1979, as quoted by Petersen & Sorensen 1981). Birds of some of these species, such as grey heron *(Ardea cinerea)*, winter in Nile Delta but the

majority appear to pass south to the savannas and wetlands of tropical Africa south of the Sahara. Some bird species passing Zaranik may belong predominantly to a single population. For example, many of the recoveries of ringed slender-billed gull in Egypt are from birds ringed of a single colony on Orlov Island in the Black Sea (Goodman & Meininger 1989). The origin of the enormous numbers of garganey passing over Zaranik are thought to come chiefly from the former Soviet Union and the majority winter in tropical West Africa including Senegal, Gambia and northern Nigeria.

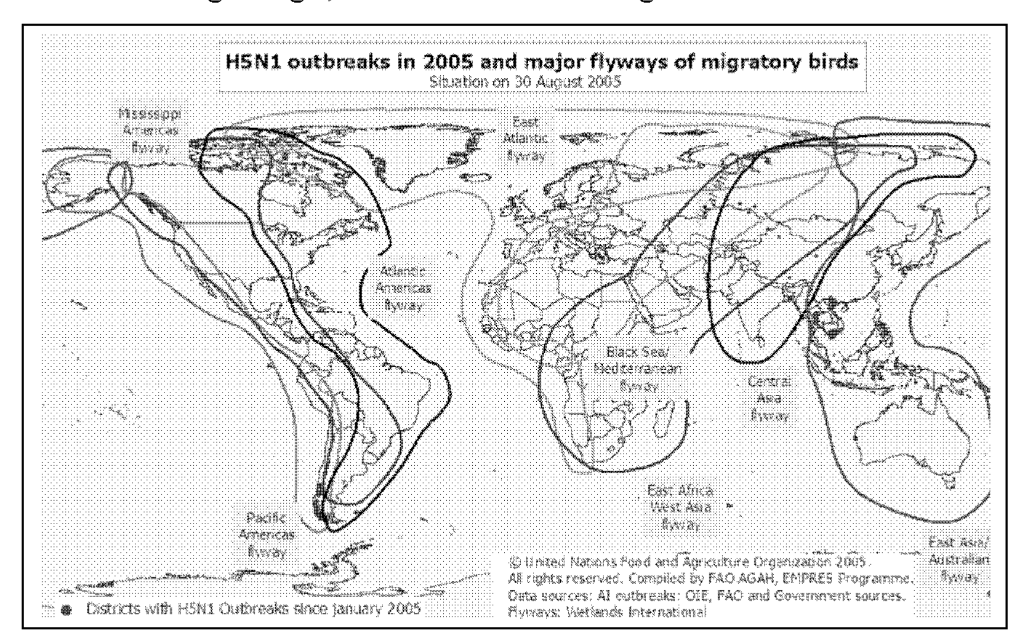


Fig. 12.1. **Major flyways of migratory birds (situation on 30 August 2005)**

12.5 QUAIL NETTING

At present, quail netting is still one of the most popular activities among the inhabitants of the Northern coast of Egypt. Every autumn from early September to late October, several hundreds of families stretch their nets continuously along the Mediterranean coast, migrating quails fall in these nets (Fig 12. 2). Most of the trapped quails are then taken to several markets located in the coastal cities through middlemen.

The most popular quail markets are present in El Arish, Port Said, Damietta, Alexandria, and some other smaller markets are distributed around the coastal villages. Some catchers may sell their quails directly to travelers on the road or to restaurants and hotels or even present some of the catch to relatives and friends, therefore it was very difficult for researchers to know the real number of annual netted quails. The most intensive quail netting occurs in North Sinai with trammel nets cover distance of about 77 km long from Rafah to Lake Bardawil. The number of hunters includes 500 families (Baha El Din &

Salama 1990), most of them are fishermen and farmers during the rest of the years. In 1981, quail catch in North Sinai was estimated to be 70,000 (Stouthamer & Bennet 1982); in 1988, the estimated catch was 160,000 (Varty 1990), while Baha El Din & Salama (1990) estimated a number of 116,000 to be the catch of that season. Goodman *et al.* (1989) estimated the annual catch from North Sinai as much as 50,000-170,000.



Fig. 12.2. **Quail nets along Sinai Mediterranean coast.**

Generally, quail netting has several meaning for different catchers depending on quality of jobs they have. For some it means an important cropping season of getting some income. For other people, who manage agriculture land or other stable jobs, it means a kind of traditional hunting inherited from the ancestors. In North Sinai, where 500 families are involved in quail netting every season, the activity has probably a most economic value compared with the other netting areas in Egypt. In 1990 season, it was estimated that quail netting generated a total of about LE 500,000 which was a modest contribution to the local economy. The average net profit per quail catcher averaged between LE 750 and LE 1050, considering that each quail catcher family consume some of the catch and give some free to relatives. The final profit is considered good compared with the average income in Egypt (LE 1500). Furthermore, quail netting provide some profits to owners who rent their land to quail catchers for about LE 150 - 400 per season. The final

conclusion was that quail netting is important to relatively small number of people, but is of limited value for the local economy (Baha El Din & Salama 1991).

12.6. TRAPPING BIRDS OF PREY

Trapping birds of prey is an increasing activity among the inhabitants of the Mediterranean coast of Sinai. North Sinai with its position on the major migration routes is considered as one of the best areas in Egypt, if not in the whole Middle East, to trap falcons. The main target of this activity is the large falcons such as lanner (*Falco biarmicus*), saker (*Falco cherrug*), and peregrine (*Falco peregrinus*), the later species is the most demanded and valued by the rich falconers from the Arab Gulf States. In North Sinai, the trapping season lasts approximately 45 days during October and November (Baha El Din & Salama 1991). The trapped falcons are mostly sold to falconers from the Gulf States through a middleman passed either in Kafr Saad (Sherkia Governerate) or in Abu Rawash (Giza Governerate).

Several non-target small falcons such as kestrel (*Falco tinnunculus*); red-footed falcon (*Falco vespertinus*) and hobby (*Falco subbuteo*) are trapped in North Sinai. Varty (1990) stated that several thousands of small falcons, mostly kestrel and red-footed falcons were trapped in North Sinai in the autumn of 1989. Baha El Din & Salama (1991) found a total of 680 birds of prey offered for sale at El Arish market in the period from September to mid October, the majority of them were small falcons.

The number of persons involved in trapping falcons is not exactly known, however Goodman *et al.* (1989) reported that there are a few professional falconers in Egypt but many hundreds could be involved in trapping falcons and other birds of prey. Petersen & Sorensen (1981) saw only two falcon trappers in Zaranik (North Sinai) during autumn 1980. Baha El Din & Salama (1991) estimated a number of 400 falcon catchers along 200 km of shoreline in North Sinai.

The number of target falcons being trapped every year is not exactly known, however several attempts were made to estimate the annual catch of falcons. 5-7 large falcons were the estimated catch from North Sinai in the season of 1980 (Petersen & Sorensen 1981). 30 - 40 large falcons was the proposed number for the whole Egypt, but in an exceptional year the catch could be over 100 birds (Goodman & Meininger 1989). Baha El Din & Salama (1991) interviewed several falcon catchers who agreed that about 40 large falcons were the catch in the season of 1989 in North Sinai.

The price paid for large falcons vary according to the species, age, sex and the health condition of the bird. However, the prices for a healthy peregrine falcon showed an increase from LE 100 in 1970 to LE 8000 in 1978 (Mullie & Meininger 1985). Petersen & Sorensen (1980) reported a price of LE 10,000 for

one peregrine. In 1990 the price ranged between LE 25,000 and LE 30,000 (Baha El Din & Salama 1991). The great price of the peregrine falcon has a magic effect that stimulates more catchers to try their luck in catching the falcon (or the treasure) that can completely change their life style. Despite that, the final economic value of this activity to the local community is not significant as only very few individuals receive the gains (Baha El Din & Salama 1991). Furthermore, the economic value from the trade of other birds of prey is even less significant as they are offered for very low prices. In 1989 the prices of a kestrel ranged between LE 3 - 7; red-footed falcons for LE 3-10, hobby for LE 25 – 50, sparrowhawk for LE 30 and honey buzzard for LE 50 (Varty 1990). Baha El Din & Salama (1991) estimated that the income of selling 680 birds of prey at El Arish market in 1990 would generate a revenue not more than LE 3000 and that the economic return for each catcher who succeeds in selling all his catch in season would be about LE 30.

In north Sinai, small birds are trapped accidentally as non-target birds in the trammel quail nets. The estimated number of trapped birds was 29,900 in 1990 (Baha El Din & Salama 1991); and 37,000 in 1991 (Baha El Din 1992). The most abundant trapped bird species are wheatears, turtle dove, redstarts, larks, and whitethroat. Most of the trapped birds are consumed locally and very few are offered for sale in the market of El Arish. The income of the trade in small birds in the region is negligible. Corncrake is another species which is highly demanded as a delicious meal along the northern coast of Egypt. In the autumn of 1991, it was estimated that 4600 corncrakes were caught in Egypt (Baha El Din 1992). The profit of selling all the estimated catch could revenue about LE 8500, however high proportion of the catch is eaten locally by the hunters. Therefore the economic value of hunting corncrakes is considered insignificant for the catchers apart from that it provides them with good and cheap meals during the season of the bird migration.

12.7 RECOMMENDATIONS FOR CONSERVATION

Tharwat and Hameid (2000) recommended three action areas, choice based on their urgency, importance and feasibility of addressing them successfully in Lake Bardawil. There is also a need for a more detailed long-term strategy, which should concentrate on environmental education in the region, as well as capacity building including manpower development of local conservation authorities.

12.7.1 Control of the Capture and Trade in Birds of Prey

The capture and trade of birds of prey (other than large falcon) is the most destructive and economically least justifiable bird catching activity practiced in North Sinai. There are also relatively few key trade outlets through which the birds reach the market, which make it relatively easy to ban the birds off the market. A first step in this action area is to press strongly to amend Law No. 53

for 1966, which provides protection for all birds beneficial to agriculture, including birds of prey (according to Ministerial Decree No. 66 for 1983). The law protects birds of prey from being captured and killed, but no where does it prohibit the trade in these birds. Thus, it is currently not possible to take any legal action concerning birds offered for sale on the market. It is probably unpractical to attempt banning the capture of birds of prey completely, but it might be feasible to regulate this practice, allowing the catchers to capture a certain number of large falcons every year, and prohibit completely the capture and trade of all other birds of prey. Certain catching methods which involve the use of other birds of prey as decoys should also be banned, limiting catching methods to the noose harnessed pigeon and some forms of the kafaya.

12.7.2 Creating A Viable Protected Area

The first step in this action area would be to continue the successful effort initiated in 1990, which for the first time stopped the bird catching activities within the Protected Area. This continuity is essential and should be combined with a revival in ornithological and other ecological research efforts at Zaranik, with the aim of maintaining the interest in the area and augmenting our knowledge on it. The second step of this action area is the implemention of all the other provisions of law No. 102 for 1983 concerning the protected areas.

12.7.3 Continued Communication and Support to Local Authorities

Considering the great weakness of local authorities concerned with the conservation in North Sinai, encouragement and assistance is essential. The confirmation international conservation interest could be in the form of simple encouragement letters, providing training opportunities to concerned personnel or designing joint research projects. The following actions and activities were suggested by Tharwat & Hamied (2000):

1. Establishment of a training program to train rangers in bird watching, birds identification, ringing, counting and photography in the field and lab.
2. Support the protected area with a powerful zoom video camera that will help in recording bird movement and identification.
3. Strengthen the law enforcement in the protected area.
4. Implement public awareness programs to inform people about the importance of protected areas and wildlife.
5. Establish bird observatory facilities.
6. Encourage the activity of bird watchers and find the best way to attract them.
7. Support Zaranik visitor's center with audio visual equipment and an exhibit stuffed birds to represent the avifauna of the area.
8. Publish a periodical newsletter and a field guide for the avifauna of the area.

9. Establish a page in the World Wide Web about the avifauna of the area.

10. An international conference should be held every 3 years to discuss the status of the avifauna of the area and compare it with the world status.

11. Encourage the study of birds as pests for agriculture and aquaculture in Egypt as an important factor affecting the national economy.

12. Extend the study of the Egyptian avifauna to be done seasonally for several years.

13. There is a great need for action to prevent habitat manipulation that occurs in protected areas and that often lead to damage avifauna indirectly.

14. There must be a study of EIA for any project or activity in or around the protected area.

15. Prevention of quail netting inside the protected area.

16. Establishment of a program supported by donors or international agencies for protecting the threatened bird species.

17. Encourage the local organizations and NGO's to participate in the conservation policy of the protected area.

18. A fairly uncertain estimate of the change of habitat as a result of climate change means that we are at present only able to draw general conclusions. We can, for instance, conclude that the oystercatcher numbers will decline due to the effect of climate change on the loss of both summer and winter habitats. For the time being, therefore, we are not able to make exact predictions about the consequences of climate change for the numbers of wading birds (Ens 1996). According to this, there is a great need to study the correlation between the physical factors and bird migration. Also, we need to study the correlation between physical factors in the breeding area of migratory birds, the migration timing and the behavior of migratory birds during migration.

12.8 MIGRATORY BIRDS AND TRANSMISSION OF DISEASES

In Egypt many migratory birds visit the country during late autumn and early winter seasons. This migration can not be controlled, so it is very difficult to put these birds under sanitary conditions as quarantine measures on hygienic control on their arrival to the country, although the risk of transmission of diseases from wild birds to domestic ones may occur, such as avian cholera and salmonellosis. Thus it is important to assess the role of some migratory bird species in the hazard of transmitting diseases among native domesticated birds.

12.8.1 Pathogenic Microorganisms

A total of 36 migrant birds gathered from Zaranik area (North Sinai) were used by Orabi & Toma (1989) for microbial survey: 22 quail, 4 wheatear, 3

golden oriole, 3 white wagtail and 4 king fisher. Capturing was done during the period from 13 to 31 September 1989. Cloacal swabs were taken from each bird for microbiological test. This study indicated that the cloacal swabs of quail and king fisher contained three microorganisms (*Salmonella* sp., *Echerichia coli* and *Streptococcus* sp. for quail; *Salmonella* sp., *Echerichia coli* and *Staphyllococcus* sp. for king fisher), while that of wheatear contained two microorganisms (*Echerichia coli* and *Streptococcus* sp.) (Table 12.5). On the other hand, only one microorganism was detected in the cloacal swabs of white wagtail (*Staphyllococcus* sp.) and golden oriole (*Klepsala* sp.).

12.8.2 Ectoparasites

Egypt with its unique geographic position is on the migration flyways of birds, visiting and passing. There are a wide variety of habitats in the agricultural lands, oases, big lakes and the long shores of the Red Sea and Mediterranean (Mazyad *et al.* 1999). From ancient time, the common grey quails (*Coturnix cotumix cotumix)* visit Egypt each autumn as a migratory bird (Bruun 1985, Sharshir & Desouky 2003). Quail farming began to increase in Egypt in the last few years due to its favoured meat and high production rate. Migratory and resident birds may play an important role in disseminating many pathogenic microorganisms and parasites, not only among the domestic birds, but also among other animals and man (Adams *et al.* 1986). Ectoparasitic infestation is one of the most important parasitic diseases of birds that are not markedly host specific which makes infested foreign birds potentially dangerous carriers to other habitats (Petrak 1982). Mites and lice infestations in birds are well known to cause irritation and disrupted feeding resulting in anemia, retarded growth, lowered egg production, decrease resistance and leads to loss of vitality (Manuel 1981). These ectoparasites may also be mechanical or biological vectors to the more serious viral and bacterial pathogens (El-Akabawy & Mahmoud 1995) beside its effect on the efficiency of flying.

Sharshir & Desouky (2003), examined 140 migratory quails and 140 farm-raised quails for ectoparasites during September to December 2001. In this study, nine acarina species and seven lice species were recorded from migratory quails; while six acarina species and four lice species were recorded from farm-raised quails (Table 12.6). Six acarina species were recorded in both migratory and farm-raised quails (*Megninia* sp., *Pterophagus* sp., *Cheyletiella* sp., *Falcutifer rostratus, Dermanyssus gallinae. Dermoglyphus* sp., *Cheyletus malaccensis, Cheyletus eruditus* and *Ornithonyssus sylviarum*), while three were recorded only from migratory quails (*Megninia* sp., *Cheyletiella* sp. and *Dermoglyphus* sp.). On the other hand, 3 lice species were recorded in both migratory and farm-raised quails (*Cuclotogaster heterographus, Menacanthus stramineus* and *Lipeurus caponis*). *Goniocotes* sp., *Oxylipeurus dentatus, Goniodes* sp. and *Lipeurus* sp. were recorded only from migratory quails; while *Menopon gallinae* were recorded only from farm-raised quails. The highest

population density of acarina was in *Megninia* sp. (257.4 quail^{-1} = 51.9% of total ectoparasites) in migratory quails and *Dermanyssus gallinae* (14.3 quail^{-1} = 22.4% of total ectoparasites) in farm raised quails, while the highest of lice was in *Cuclologasler heterographus* in both migratory and farm-raised quails. The highest infestation rate with total acarina was during November and September in migratory and farm-raised quails, respectively; while the highest infestation rate with total lice was during October and September in migratory and farm-raised quails, respectively.

Table 12.5. **Pathogenic microorganisms isolated from some migrant birds in Zaranik Protected Area (after Orabi & Toma 1989).**

Bird	Isolated organism				
	Salmonella sp.	*E. coli*	*Klepsala sp.*	*Staphyllococcus* sp.	*Streptococcus* sp.
Quail	+	+			+
King Fisher	+	+		+	
Wheatear		+			+
White Wagtail				+	
Golden Oriole			+		

Table 12.6. **Density of the acarina and lice ectoparasites per quail individual (after Sharshir & Desouky 2003).**

Species	Migratory quail		Farm-raised quail	
	Mean density per quail	% to total ectoparasites	Mean density per quail	% to total ectoparasites
A. Acarina				
***Pterophagus* sp.**	157.4	31.7	3.8	5.93
***Falculifer rostratus* (Buckholz)**	5.6	1.1	8.4	13.2
***Dermanyssuss gallinae* (DeGeer)**	5.1	1.0	17.3	22.4
***Cheyletus malaccensis.* (Oudemans)**	3.9	0.8	7.5	11.7
***Cheyletus eruditus* (Schrank)**	2.9	0.6	1.4	2.2
***Crnithonyssus sylviarum* (Canestrine and Franzago)**	0.5	0.1	1.9	1.0
***Dermoglyphus* sp.**	4.2	0.9	-	-
***Megninia* sp.**	257.4	51.9	-	-
***Cheyletiella* sp.**	6.1	1.2	-	-
B- Lice				
***Cuciotogiaster heterographus* (Nitzsch)**	10.7	2.2	8.9	14.0
***Menacanthus stramineus* (Nitzsch)**	8.5	1.7	6.3	9.8
***Lipeurus caponis* (Linne)**	6.7	1.4	7.6	12.0
***Goniocotes* sp.**	7.9	1.6	-	-
***Oxylipeurus dentatus* (Sugimoto)**	7.2	1.5	-	-
***Goniodes* spp.**	6.7	1.4	-	-
***Lipeurus* sp.**	5.1	1.0	-	-
***Menopon gallinae* (Linne)**	-	-	3.7	5.8

Regarding the economic and medical importance of the recorded ectoparasites, *Cheyletus malaccensis* is one of the most important mites of stored food (Hughes 1961). *Dermanyssus gallinae* can bite human causing pain, irritation and local inflammation (Cheng 1974, McDaniel 1979, Soulsby, 1982, Calnek *et al.* 1991). Mites and lice cause considerable economic losses to

poultry industry manifested by restlessness, damage of feathers, decrease in productivity, transmission of some diseases and mortality (Deloadr & Devaney 1981, Philips 1990). In general mites are involved in house dust allergy, a topic dermatitis, respiratory allergy follicular mite infestation, and human scabies (Morsy *et al.* 1993, 1994, 1995). Shoura & Morsy (1974) reported certain mite species as intermediate host of some tapeworms that infect man and other animals. On the other hand, Proctor & Ownes (2000) stated that ectoparasites play important roles in the live of birds. Among these parasites, mites offer unique potential because of their extraordinary ecological and evolutionary diversity. Not all bird-associated mites are parasitic, recent research suggests that some might even be beneficial and provide an ideal tool for the study of host life histories, sexual selection, immunocompetence and cospeciation (Sharshir & Desouky 2003).

12.8.3 Migratory Birds and Avian Influenza

The role of migratory birds in the spread of the highly pathogenic avian influenza is not fully understood. Wild waterfowl are considered a natural reservoir of all influenza A viruses. They have probably carried influenza viruses with no apparent harm for centuries. They are known to carry viruses of the H5 and H7 subtypes, but usually in the low pathogenic form. Considerable circumstantial evidence suggests that migratory birds can introduce low pathogenic H5 and H7 viruses to poultry flocks, wherein they may mutate to the highly pathogenic form. In the past, highly pathogenic viruses have been isolated from migratory birds on very rare occasions involving a few birds, usually found dead within their flight range. This finding long suggested that wild waterfowl are not agents for the onward transmission of these viruses. Recent events make it likely that some migratory birds may now be directly spreading the H5N1 virus in its highly pathogenic form. Further spread to new areas is expected.

During 2005, an additional and significant source of international spread of the virus in birds became apparent for the first time, but remained poorly understood. Scientists are increasingly convinced that at least some migratory waterfowl carry the H5N1 virus in its highly pathogenic form, sometimes over long distances, and introducing the virus to poultry flocks in areas that lie along their migratory routes. Should this new role of migratory birds be confirmed, it will mark a change in a long-standing stable relationship between the H5N1 virus and its natural wild-bird reservoir.

Evidence supporting this altered role began to emerge in mid-2005 and has since been strengthened. The die-off of more than 6000 migratory birds, infected with the highly pathogenic H5N1 virus, that began at the Qinghai Lake nature reserve in central China in late April 2005, was probably unprecedented. Prior to that event, wild bird deaths from highly pathogenic avian influenza

viruses were rare, usually occurring as isolated cases found within the flight distance of a poultry outbreak. Scientific studies comparing viruses from different outbreaks in birds have found that viruses from the most recently affected countries, all of which lie along migratory routes, are almost identical to viruses recovered from dead migratory birds at Qinghai Lake. Viruses from Turkey's first two human cases, which were fatal, were also virtually identical to viruses from Qinghai Lake.

In conclusion, the migratory birds act as carriers for many microbial infective agents, so great care must be taken in handling such birds once they are caught especially when they are slaughtered and prepared for the table.

12.9 SUMMARY

Seven main avian habitats were identified in Lake Bardawil: open sea, sea inlets, open water, saline tidal shallows, shelving shorelines, salt marshes and coastal dunes. Zaranik Lagoon, as a part of Lake Bardawil, is considered to be one of the most important wetlands for waterbirds in Egypt and the eastern Mediterranean. Two hundred and forty-two species have been recorded from this Protected Area (51.5% of the total avian species recorded in Egypt). These species belong to 121 genera, 48 families and 21 orders. The well represented families are Sylviidae (26 species), Scolopacidae (25 species), Laridae (20 species), Accipitridae (18 species), Turdidae (15 species) and Anatidae (14 species). On the other hand, 18 families are represented each by only one.

Of the 242 species and subspecies recorded in Lake Bardawil, 67 are residents(26.7%). The migratory birds represent about 72.3% of the total recorded species in Zaranik. Out of 17 bird species listed in Egypt as endimic species, the collection of information about the national and world distribution of the birds in Lake Bardawil indicated the possibility of occurrence of only one endemic species: *Streptopelia senegalensis aegyptiaca*.

Many birds passing through the Zaranik Protected Area originate from the populations breeding over a large area of Eurasia and they winter across similarly huge areas of north and sub-Saharan. For instance, recoveries of ringed birds show that a significant part of the migrating Herons of Zaranik come from breeding grounds around the Avov Sea and Volga. Birds of some of these species, such as grey heron *(Ardea cinerea)*, winter in Nile Delta but the majority appear to pass south to the savannas and wetlands of tropical Africa south of the Sahara.

At present, quail netting is still one of the most popular activities among the inhabitants of the Northern coast of Egypt. Every autumn from early September to late October, several hundreds of families stretch their nets continuously along the Mediterranean coast, most of the migrating quails fall in these nets. Most of the trapped quails are then taken to several markets located in the coastal cities through middlemen.

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Three action areas, based on their urgency, importance and feasibility of addressing them successfully in Lake Bardawil are recommended:

1- control the capture and trade in birds of prey, 2- creating a viable protected area, and 3- continued communication and support to local authorities. There is also a need for a more detailed long-term strategy, which should concentrate on environmental education in the region, as well as capacity building including manpower development of local conservation authorities.

The cloacal swabs of quail and kingfisher contained three microorganisms (*Salmonella* sp., *Echerichia coli* and *Streptococcus* sp. for quail; *Salmonella* sp., *Echerichia coli* and *Staphyllococcus* sp. for kingfisher), while that of wheatear contained two microorganisms (*Echerichia coli* and *Streptococcus* sp.). On the other hand, only one microorganism was detected in the cloacal swabs of white wagtail (*Staphyllococcus* sp.) and golden oriole (*Klepsala* sp.). In addition, 9 acarina species and 7 lice species were recorded from migratory quails; while six acarina species and four lice species were recorded from farm-raised quails. Six acarina species were recorded in both migratory and farm-raised quails, while three were recorded only from migratory quails. On the other hand, 3 lice species were recorded in both migratory and farm-raised quails : *Goniocotes* sp., *Oxylipeurus dentatus*, *Goniodes* sp. and *Lipeurus* sp. were recorded only from migratory quails; while *Menopon gallinae* were recorded only from farm-raised quails. In conclusion, the migratory birds may act as carriers for many microbial infective agents, so great care must be taken in handling such birds once they are caught especially when they are slaughtered and prepared for the table.

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12.11 PLATES OF BIRDS: 12.1 – 12.9

(Courtsey from the managing team of Zaranik Protected Area)

Plate 12.1

Pelecanus onocrotalus

Ardea purpurea purpurea

Ardeola ralloides

Egretta garzetta garzetta

Ixobrychus minutus minutus

Nycticorax nycticorax nycticorax

Plate 12.2

Phoenicopterus ruber roseus

Anas querquedula

Falco tinnunculus tinnunculus

Coturnix coturnix coturnix

Crex crex

Plate 12.3

Gallinula chloropus chloropus

Haematopus ostralegus ostralegus

Himantopus himantopus himantopus

Recurvirostra avosetta

Charadrius hiaticula tundrae

Pluvialis squatarola squatarola

Plate 12.4

Calidris alba

Numenius arquata arquata

Chlidonias niger niger

Gelochelidon nilotica nilotica

Larus fuscus fuscus

Larus genei

Plate 12.5

Larus hemprichii

Sterna albifrons albifrons

Alcedo atthis atthis

Halcyon smyrnensis smyrnensis

Upupa epops epops

Jynx torquilla torquilla

Plate 12.6

Hirundo rustica savignii

Riparia riparia shelleyi

Galerida cristata maculata

Motacilla flava pygmaea

Lanius collurio collurio

Lanius senator senator

Plate 12.7

Acrocephalus arundinaceus arundinaceus

Acrocephalus schoenobaenus

Phylloscopus sibiatrix

Prinia gracilis gracilis

Sylvia borin borin

Sylvia communis communis

Plate 12.8

Sylvia curruca curruca

Ficedula parva parva

Muscicapa striata striata

Oenanthe oenanthe oenanthe

Phoenicurus phoenicurus phoenicurus

Saxicola rubetra rubetra

Plate 12.9

Emberiza hortulana

Plegadis falcinellus

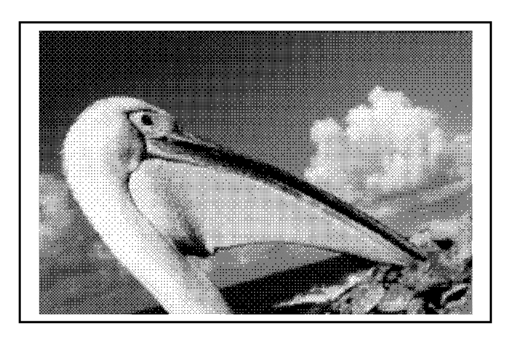
Platalea leucorodia leucorodia

Anas querquedula

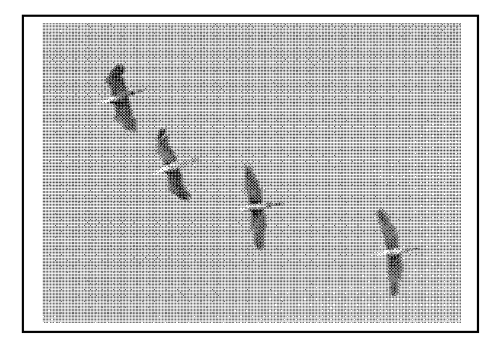
Calidris canutus canutus

Sterna caspia caspia

Plate 12.1

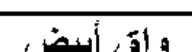


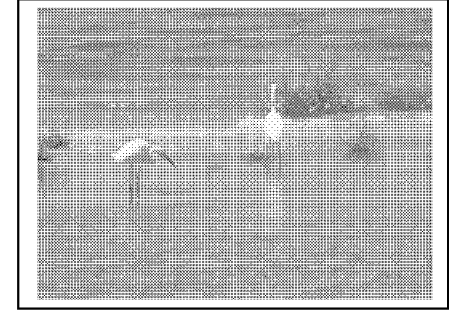
Pelecanus onocrotalus جمل البحر - بجع أيض



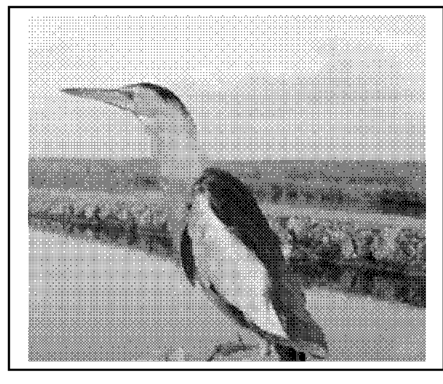
Ardea purpurea purpurea مالك الحزين - جحفة



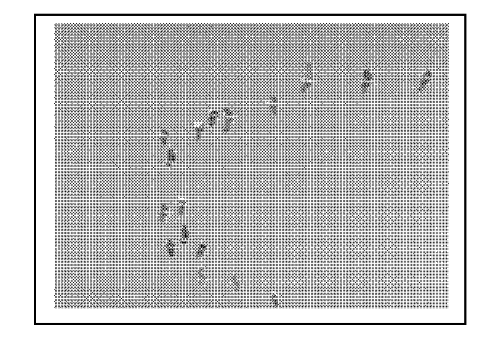
Ardeola ralloides  واق أبيض



Egretta garzetta garzetta بلشون أبيض - أبو بليقة

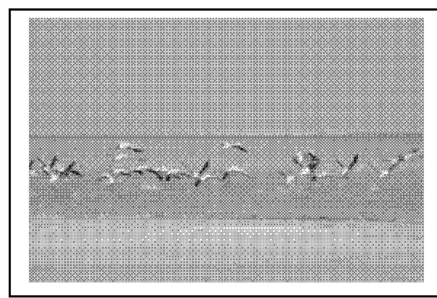


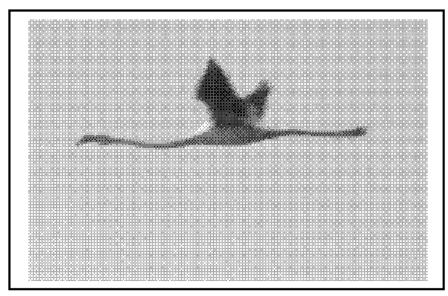
Ixobrychus minutus minutus أبو قردان - غرنوج



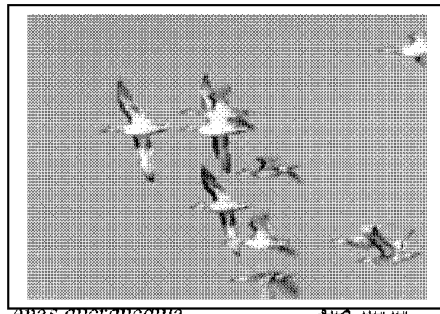
Nycticorax nycticorax nycticorax غراب الليل – واق الشجر

Plate 12.2

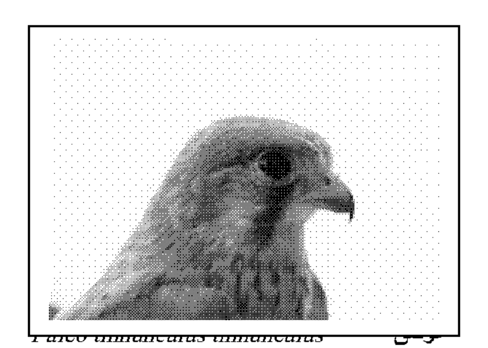




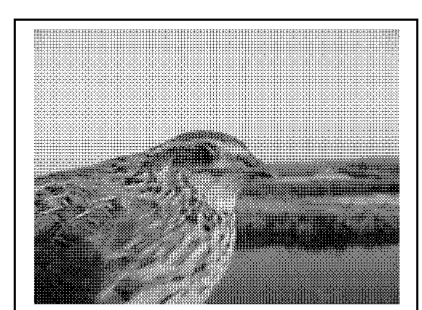
Phoenicopterus ruber roseus بشاروش ـ نحام



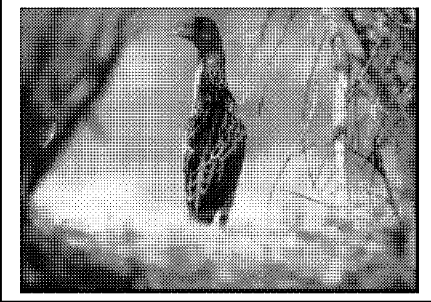
Anas querquedula سرسير صيفي



Falco tinnunculus tinnunculus [illegible]



Coturnix coturnix coturnix سلوى ـ سمان

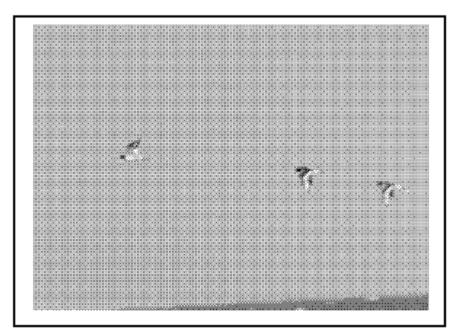


Crex crex مرعة الغلة

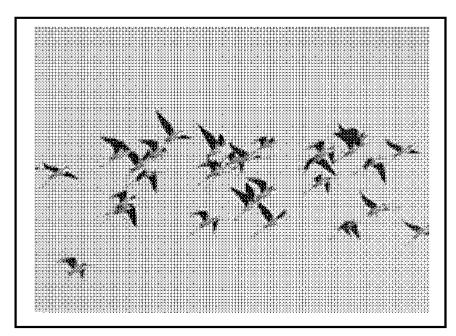
Plate 12.3



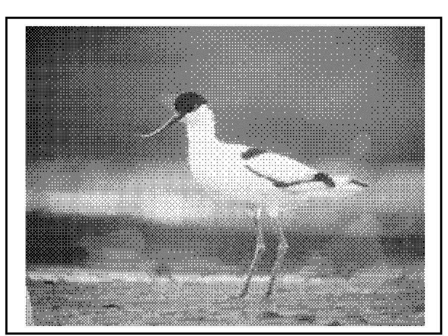
Gallinula chloropus chloropus دجاجة الماء



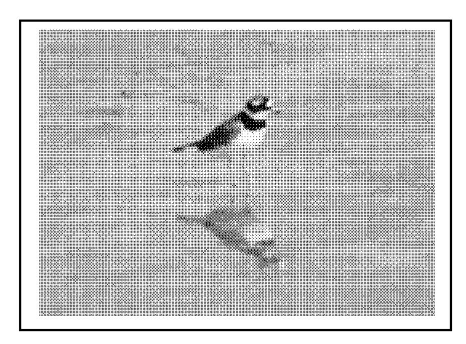
Haematopus ostralegus ostralegus آكل المحارة بجع البحر



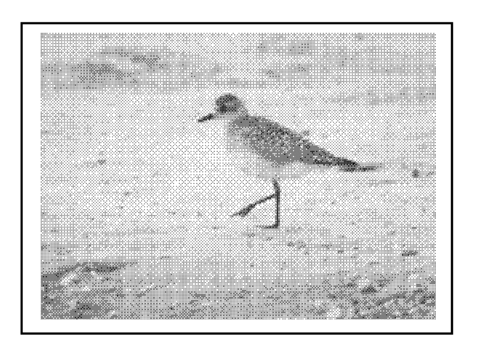
Himantopus himantopus himantopus أبو المغازل - أبو قصبة



Recurvirostra avosetta حليبى - نكات

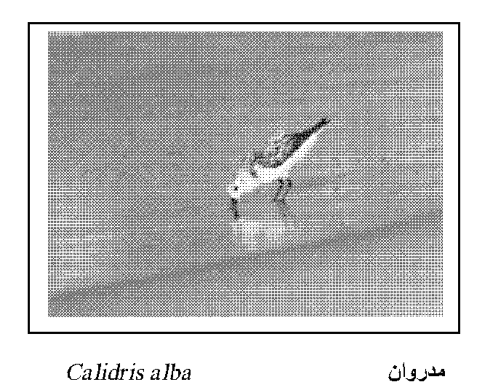


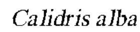
Charadrius hiaticula tundrae قطقاط متوج كبير - زقزاق



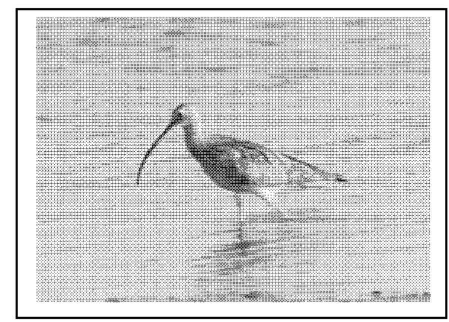
Pluvialis squatarola squatarola قطقاط رمادى

Plate 12.4





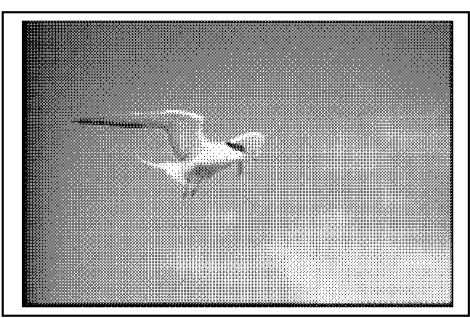
Calidris alba مدروان



Numenius arquata arquata كروان الغيط



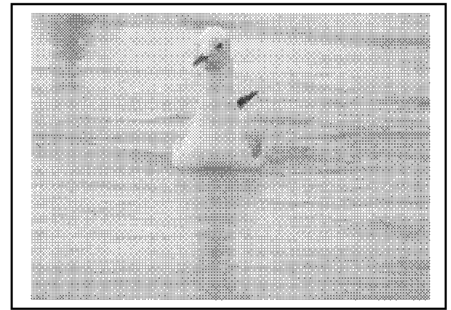
Chlidonias niger niger خطاف أسود - خرشنة



Gelochelidon nilotica nilotica خطاف نورسى المنقار اويق

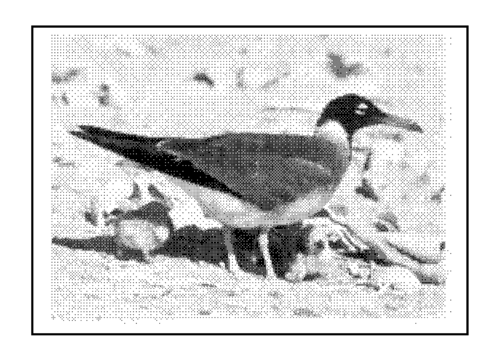


Larus fuscus fuscus نورس دغبة - جوكة

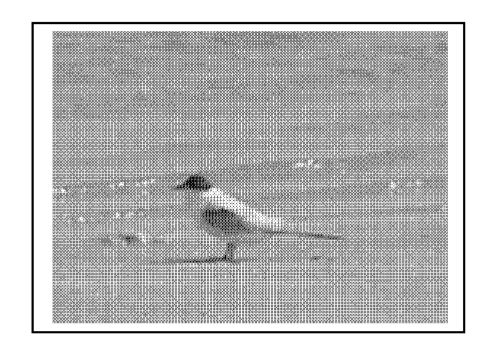


Larus genei نورس قرقطى

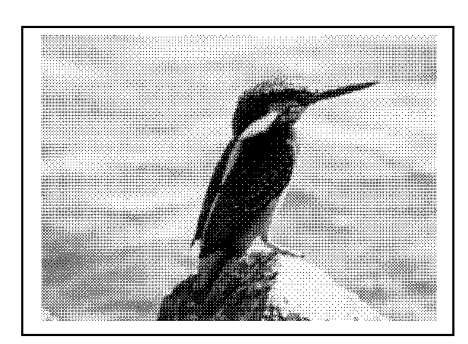
Plate 12.5



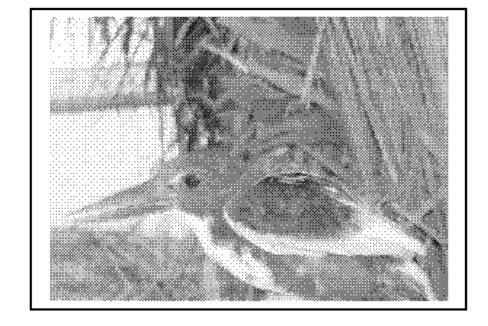
Larus hemprichii نورس اسحم



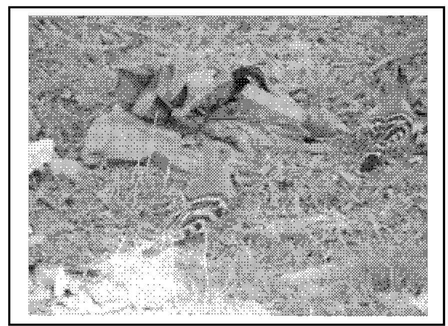
Sterna albifrons albifrons خطاف صغير ـ دغيز



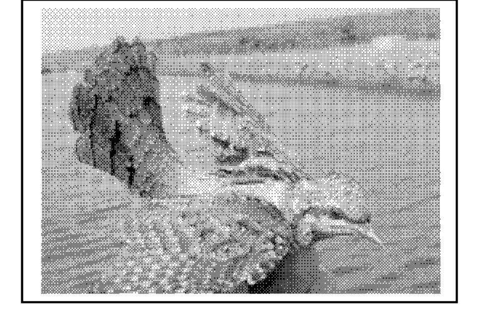
Alcedo atthis atthis صياد السمك ـ رفراف



Halcyon smyrnensis smyrnensis 

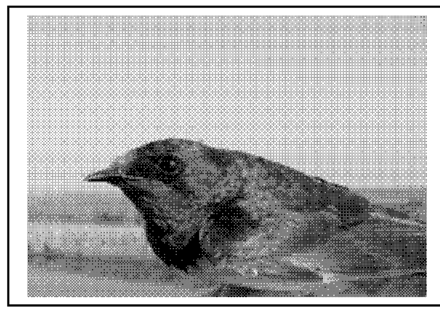


Upupa epops epops هدهد

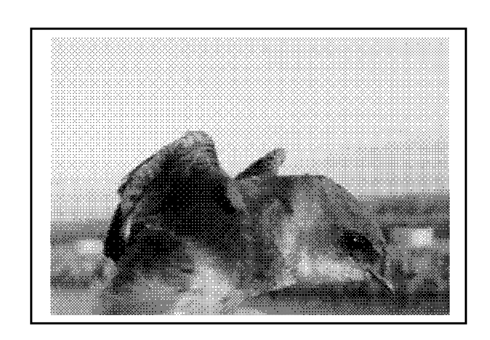


Jynx torquilla torquilla لواء ام الواء

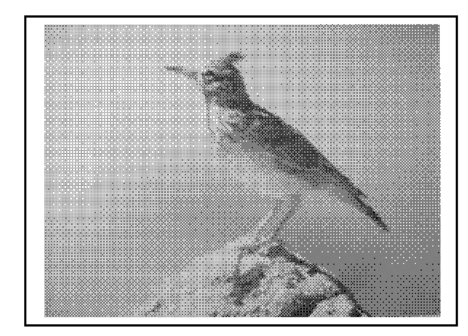
Plate 12.6



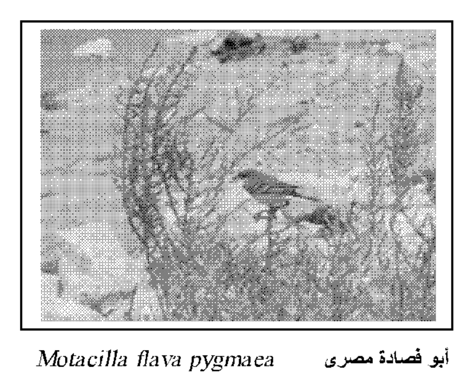
Hirundo rustica savignii عصفور الجنة



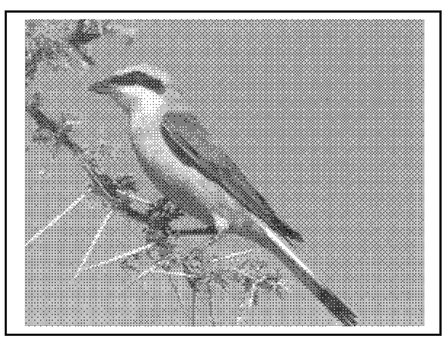
Riparia riparia shelleyi سنونو الشواطىء



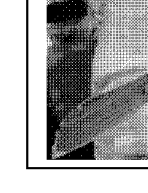
Galerida cristata maculata قنبرة بشوشة، قنبرة متوجة

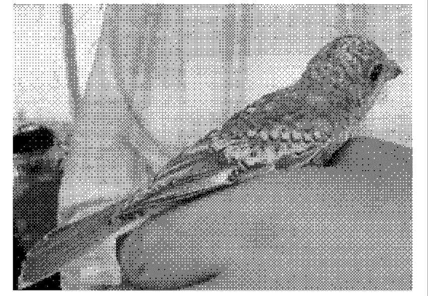


Motacilla flava pygmaea أبو فصادة مصرى



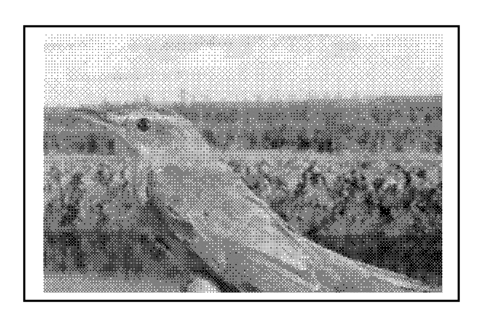
Lanius collurio collurio دقناش أكحل





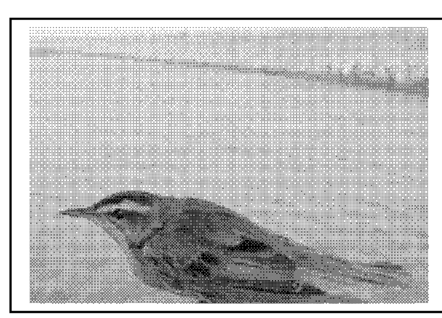
Lanius senator senator دقناش اوربى، دقناش شامى

Plate 12.7



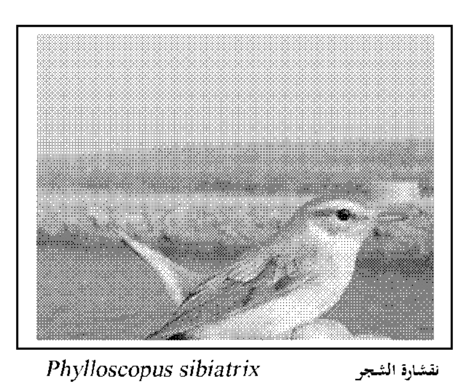
Acrocephalus arundinaccus arundinaccus

هازجة القصب الكبير



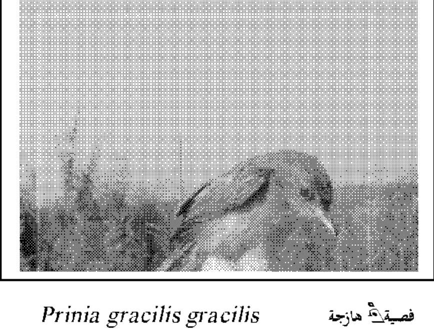
Acrocephalus schoenobaenus

هازجة السعد وش الدبية

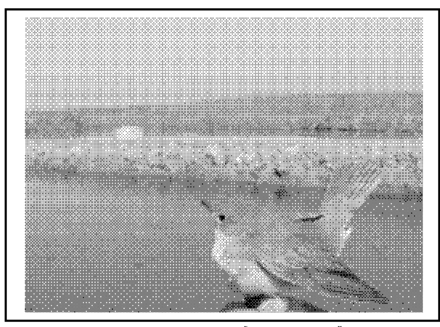


Phylloscopus sibiatrix نقشارة الشجر

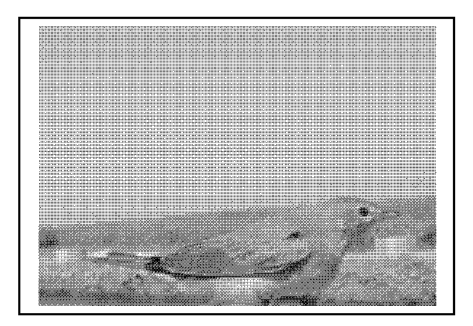




Prinia gracilis gracilis فصية هازجة

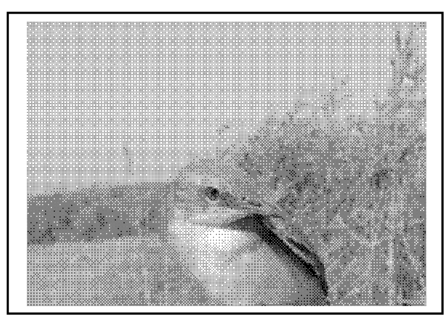


Sylvia borin borin دخلة كحلة أدخلة البساتين أقرقفة

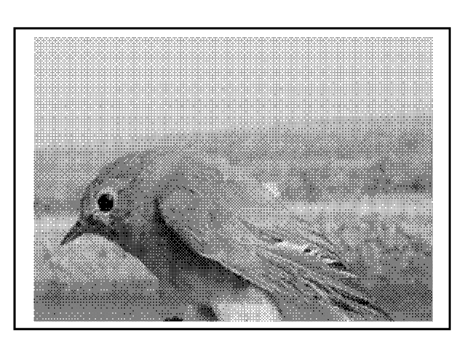


Sylvia communis communis زريقة فيراني

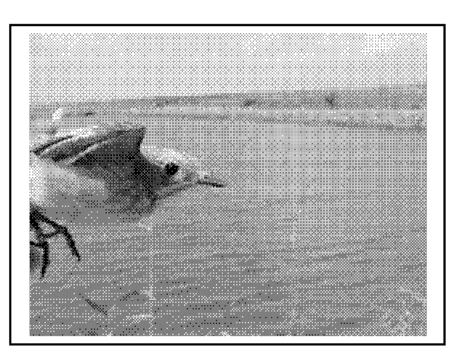
Plate 12.8

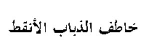


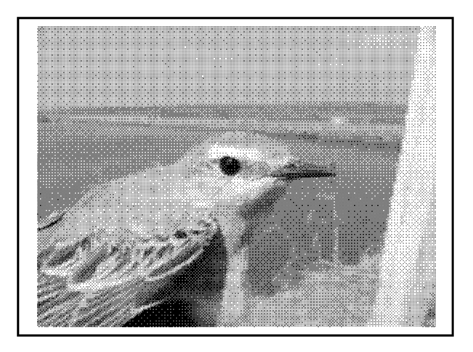
Sylvia curruca curruca زريقة فيراني دخلة فيراني



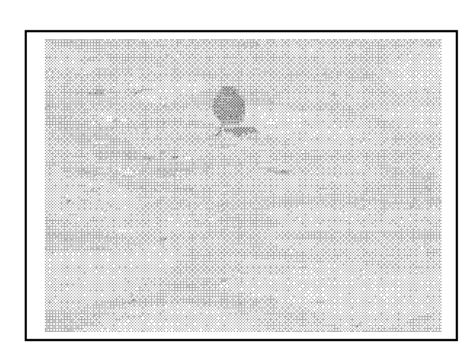
Ficedula parva parva خاطف الذباب احمر الصدر



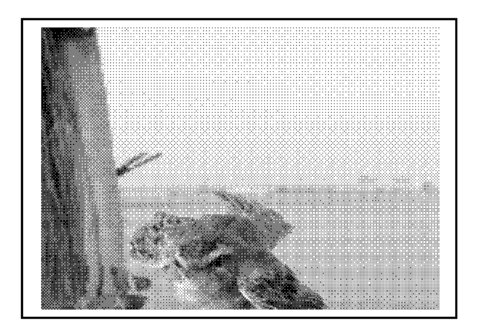
Muscicapa striata striata 
خاطف الذباب الأنقط



Oenanthe oenanthe oenanthe أبلق ابو بليق

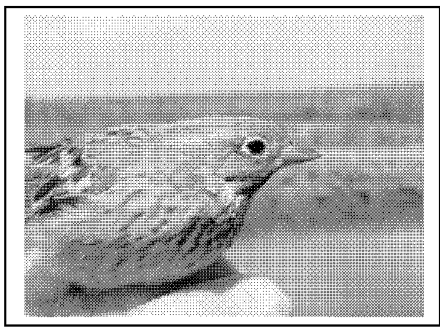


Phoenicurus phoenicurus phoenicurus حميراء

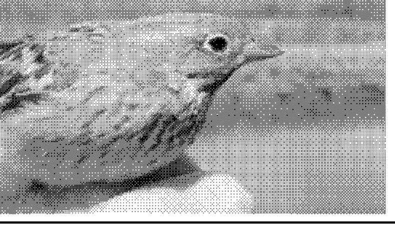


Saxicola rubetra rubetra قليعي أحمر أفسوقة

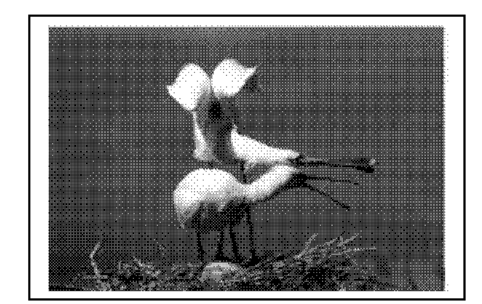
Plate 12.9



Emberiza hortulana درسة الشعير



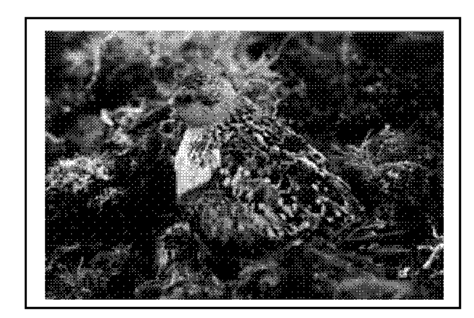
Plegadis falcinellus أبو منجل أسود



Platalea leucorodia leucorodia أبو ملعقة



Anas querquedula شرشير صيفى



Calidris canutus canutus دريجة الشمال



Sterna caspia caspia خطاف ابو بلحق خطاف ابو جرة

Chapter 13
Mammals

Hart (1891) published the first annotated list of the mammals of Sinai. Several publications dealing specifically with the mammals of Sinai followed, including those of Bonhote (1912), Thomas (1919), Bodenheimer & Theodor (1929), Wassif (1944, 1953, 1954), Wassif & Hoogstraal (1953) and Haim & Chernov (1974). Numerous publications on the mammals of Egypt also covered those of Sinai. Most important among these are Anderson (1902), Flower (1932), El-Negumi (1952), Setzer (1957, 1958a, b, c, d, 1961a, b, 1963), Hoogstraal (1962, 1963, 1964) and Osborn & Helmy (1980).

Haim & Chernov (1974) studied the distribution and ecology of myomorph rodents from the sea level to the south Sinai highlands. Saleh (1993) reviewed available information on habitats of land mammals of Egypt including Sinai. Saleh & Basuony (1997, 1998) wrote a recent contribution to the mammals of Sinai Peninsula with notes on the ecological distribution and feeding ecology.

13.1 SPECIES COMPOSITION

Basuony (2003) studied the mammalian fauna in Bardawil region and Zaranik Protected Area (ZPA) during 2002. He recorded twenty one species representing, sixteen genera eleven families and five orders (Table 13.1).

The long-eared hedgehog *Hemiechinus auritus* appeared to be much more widespread throughout northern Sinai than formerly believed. Several specimens were collected throughout the study area. The taxonomic positions of specimens from the area, however, are not clear (Osborn & Helmy 1980). *Hemiechinus auritus* from the Nile Valley has been placed under the subspecies *aegyptius*, while populations from the Mediterranean coastal belt of the Western Desert and the western fringes of the Nile Delta have been identified as *Hemiechinus auritus libycus*. Specimens from northern Sinai are generally much lighter than other Egyptian populations and have been tentatively placed under the subspecies *aegyptius*. The previous record of the hedgehog is from El-Arish only. The subspecific status of the north Sinai population is now under investigation.

An adult female shrew was collected in a pitfall trap set for insects on a small island in Zaranik. The specimen was identified as *Crocidura nana*, according to the keys of Osborn & Helmy (1980). The presence of *C. nana* in northern Sinai, in such an atypical habitat is rather intriguing. The possibility of a relict status of this population, as Lake Bardawil is known to have been a part of the Nile basin system in ancient times, could provide a plausible explanation. The presence of this species in the ZPA presents an invaluable opportunity for studying the biology and ecology of this species. This record is the first of this shrew in the Sinai Peninsula.

Basuony (2003) did not collect bats from the study area during his survey. However, several species have been recorded by other authors from Northern Sinai coastal areas including the study area. *Rhinolophus clivosus* was recorded from El-Arish in northern Sinai by Wassif (1953a) as *R. acrotis* and by Qumsiyeh (1985). Hoogstraal (1962) and Qumsiyeh (1985) recorded *Asellia tridens* from El-Arish town, and Wassif (1953 a) collected *Otonycteris hemprichii* from the same area. Wassif (1953a) also collected *Pipistrellus kuhlii* from Maqdabah, 30 km south of El-Arish. One specimen of the same species was recorded from the Zaranik area by Harrison & Bates (1991).

Basuony (2003) recorded *Lepus capensis sinaiticus* on several occasions throughout the study area. The species has been previously recorded in Sinai from El-Quseima, Wadi Raha, Wadi Feiran, Wadi El-Sheikh, Saint Catherine Monastery, Gabal El-Maghara, Elwate El-Agramiya and Ras El-Naqab (Murray 1912, Flower 1932, Wassif 1953a, Setzer 1958b, Osborn & Helmy 1980, Saleh & Basuony 1998). Basuony (2003) records add northern Sinai to the geographical range of this hare that now appears to cover the entire Peninsula.

Gerbillus pyramidum is a common rodent throughout the vegetated interdune areas and around human habitations within Bardawil area, where several specimens were collected. The species was also reported from semi-stabilized dunes (Abramsky & Pinshow 1989). The subspecific status of this species is *floweri*.

Several individuals of *Gerbillus andersoni bonhotei* were collected throughout the area, particularly among the sand dunes and on many of the islands. The species has been previously recorded only from northeastern Sinai (Flower 1932, Wassif 1953a, Osborn & Helmy 1980). This is the first record of this gerbil from the region of northern Sinai including El-Arish.

The results of Basuony (2003) support previous reports that *Gerbillus gerbillus* is widespread throughout North Sinai and add the Zaranik area to its geographical range. The species has been previously recorded from the Sinai coast of the Gulf of Suez and northeastern Sinai (Osborn & Helmy 1980) and Bir El-Abd area (Saleh & Basuony 1998) as well as other numerous localities throughout the peninsula.

Table 13.1. **Mammals recorded from Bardawil region and Zaranik Protected Area (after Basuony 2003).**

Order	Family	Species	English name	Arabic name
Insectivora	**Erinaceidae**	*Hemiechinus uritus*	Long eared hedgehog	القنفد طويل الأذن
	Soricidae	*Crocidura nana*	Dwarf Shrew	الزباب القزم
Chiroptera	**Rhinopomatidae**	*Rhinolophus clivosus*	Horse shoe Bat	الخفاش حدوة الفرس
	Hipposideridae	*Asellia tridens*	Leaf-nosed Bat	خفاش ورقي الأنف
	Vespertilionidae	*Pipistrellus kuhlii*	Kuhl's Bat	خفاش كول
		Otonycteris hemprichii	Long-eard Bat	خفاش همبرش
Lagomorpha	**Leporidae**	*Lepus capensis*	Sinai Hare	أرنب الكاب
Rodentia	**Cricetidae**	*Gerbillus pyramidum*	Greater Gerbil	الدمسي
		Gerbillus andersoni	Anderson's Gerbil	جربيل اندرسون
		Gerbillus gerbillus	Lesser Gerbil	البيوضي
		Dipodillus dasyurus	Wagner's Dipodil	جربيل فاجنار
		Meriones crassus	Silky Jird	جرد كراسوس
		Meriones sacramenti	Negev Jird	جرد النقب
		Psammomys obesus	Fat Sand rat	جرد- فأر الرمل
	Muridae	*Rattus rattus*	Black Rat	جرد اسود
		Mus musculus	House Mouse	فأر المنزل
	Dipodidae	*Jaculus orientalis*	Greater Jerboa	اليربوع الكبير
		Jaculus jaculus	Lesser Jerboa	اليربوع الحر
Carnivora	**Canidae**	*Vulpes zerda*	Fennec Fox	الفنك
	Felidae	*Felis silvestris*	Wild Cat	قط جبلي
		Felis margarita	Sand Cat	قط الرمال
5	**11**	**21**		

One specimen of *Dipodillus dasyurus* was captured from El Flosiyat island. Both Osborn & Helmy (1980) and Haim & Chernov (1974) did not report *D. dasyurus* from littoral areas of Sinai; however, Saleh & Basuony (1998) recorded this species fiom coastal plains of Nabq and Abu Gallum on the Gulf of Aqaba coast.

Haim and Chernov (1974) presented a map showing the distribution range of *Meriones crassus* in Sinai covering almost the entire Peninsula without giving specific collection localities. *Meriones sacramenti* has been recorded only from the northeastern corner of Sinai, Rafah and Bir Lehfan (Wassif 1953a). Individuals of both species were trapped in the vegetated parts of the study area. *Meriones sacramenti* is recorded for the first time from Bardawil area in north Sinai.

The strictly diurnal fat sand rat, *Psammomys obesus*, was observed and collected on the Flosiyat island and other halophyte-covered localities in Bardawil area. These specimens are relatively dark as compared with other subspecies in Egypt. The subspecies *terraesanctae* is the subspecies reported to occur in northern Sinai and the northern part of the Eastern Desert (Osborn & Helmy1980). *P. obesus* inhabits saline areas and salt marshes with stands of succulent halophytic plants such as *Halocnemon strobilaceum*, *Salicomia fruticosa* and *Anabasis articulata* in Bardawil area.

Jaculus orientalis has not been previously recorded from northern Sinai. But, Basuony (2003) *observed* one individual on the Flosiyat island. Previous records of this jerboa in Sinai come from southwestern region on the Gulf of Suez littoral (Anderson 1902, Setzer 1958a, Hoogstraal 1963, Haim & Chernov 1974, Osborn & Helmy 1980).

Jaculus jaculus was very numerous in the sandy areas including many of the islands where individuals were both collected and observed at night. Wassif (1953 a) recorded *Jaculus jaculus* from El-Arish and Gebel Lehfan. However, Osborn & Helmy (1980) recorded it only from south western Sinai.

Basuony (2003) observed the fennec fox, *Vulpes zerda*, in the sandy areas of ZpA and southward to Al-Maghara. Tracks and burrows were common between stands of *Artemisia monosperma* in sand dunes. The colour of fennec foxes in Bardawil area appears to be somewhat paler than those of Western Desert of Egypt

Only one skull of wild cat, *Felis silvestris,* was obtained from Zaranik area in a sandy depression near the visitor's centre of ZpA. Tracks of wild cats throughout the area eastward to Al- Medan, westward to Bir El-Abd and southward to Al-Maghara were also found. The wild cat is well known to local Bedouins, who claim that they frequently prey on their poultry. The subspecific status of this wild cat is reported to be *tristrami* (Osborn & Helmy 1980). *Felis silvestris* is recorded only from a few sites in the Peninsula such as Wadi El-Arish, Abu Gallum, Abu Dura mines, Gabal El-Maghara and Wadi El-Arbeen (Flower 1932, Harrison 1968, Osborn & Helmy 1980, Saleh & Basuony 1998). These records and that of Basuony (2003) study add northern and northwestern Sinai Peninsula to the geographical range of this cat.

Tracks of the sand cat *Felis margarita* were seen at different localities in Bardawil area. This species is present in the northern region of Sinai according to the verbal reports of the local Bedouins inhabiting the patch sites of the area. Saleh & Basuony (1998) recorded *Felis margarita* from Bir El-Abd and Gebel El-Maghara.

13.2 ZOOGEOGRAPHICAL AFFINITY

Egypt is a part of the largest stretch of desert that extends from Mauritania to Arabia, southwestern Asia and northwestern India. This area is considered a subregion of the Palearctic (Zohary 1973) or a transition zone between the Palearctic and the Paleotropical regions (Muller 1973). The mammals of the Sahara and Arabia, including most of Egypt, were also termed Saharo-Sindian (Harrison 1964, Ranck1986, Atallah 1977, Qumsiyeh 1985). The fauna of North Africa, however, changed drastically in the Pleistocene. During the Tertiatry, there was an essentially endemic African fauna, which was preserved until the Quaternary, towards the end of which "certain Eurasian elements penetrated to North Africa, probably by way of the Near East and

Suez" (Arambourg 1966). It is of interest to investigate the importance of Egypt and the Nile Valley for mammal distributions as an area connecting Africa, Asia and Europe.

Osborn & Helmy (1980) marginally touched the zoogeography of the land mammals of Egypt. Saleh & Basuony (1997, 1998) dealt with the zoogeography of the mammalian species in the Peninsula.

Table 13.2 shows the main zoogeographical affinities of mammalian species recorded from the study area of Zaranik. Of the twenty one species recorded from Bardawil area, fourteen species *(Hemiechinus auritus, Asellia tridens, Otonycteris hemprichii, Gerbillus pyramidum, Gerbillus andersoni, Gerbillus gerbillus, Dipodillus dasyurus, Meriones crassus, Meriones sacramenti, Psammomys obesus, Jaculus orientalis, Jaculus jaculus, Vulpes zerda* and *Felis margarita)* are Saharo-Sindian forms that have a wide distribution in the Sahara and southwestern Asia. Four species belong to the genera *Pipistrellus, Lepus, Rattus and Mus* are considered cosmopolitan with almost worldwide distribution. *Rhinolophus clivosus* and *Crocidura nana* are the only Afrotropical species (distributed in Africa south of Sahara). *Pluriregional* species, that have distribution in the Mediterranean and the Saharo-Sindian regions, are represented by *Felis silvestris* only.

Table 13.2 **Mammals recorded from Bardawil and Zaranik areas and their major zoogeographical subdivisions (Qumsiyeh 1985). AF=Afrotropical; SS= Saharo-Sindian; PL= Pluririgional; WD= Widespread (after Basuony 2003)**

Species	AF	SS	PL	WD
Hemiechinus auritus		+		
Crocidura nana	+			
Rhinolophus clivosus	+			
Asellia tridens		+		
Pipistrellus kuhlii				+
Otonycteris hemprichii		+		
Lepus capensis				+
Gerbillus pyramidum		+		
Gerbillus andersoni		+		
Gerbillus gerbillus		+		
Dipodillus dasyurus		+		
Meriones crassus		+		
Meriones sacramenti		+		
Psammomys obesus		+		
Rattus rattus				+
Mus musculus				+
Jaculus orientalis		+		
Jaculus jaculus		+		
Vulpes zerda		+		
Felis silvestris			+	
Felis margarita		+		
21	**2**	**14**	**1**	**4**

On the basis of the present species the mammalian fauna of north Sinai is quite similar to that of northern Arabia and eastern Mediterranean. This may be attributed to certain features of Sinai as a land bridge between the continents of

Asia and Africa, where there is no major ecological barrier between Sinai and the rest of Asia. This explains the occurrence of 14 Saharo-Sindian species.

The mammalian species recorded by Basuony (2003) are distributed among a wide range of habitats. Coastal and halophytic communities, inland sand dunes and agricultural land and artificial landscapes represent the basic, recognizable habitat types in the study area. Coastal and halophytic communities include sand and mud flats, salt marshes, coastal sand dunes and islets. Inland sand dunes cover the southern regions of the area. The dunes are mostly barren, although troughs between the dunes are often vegetated. Rain water accumulating beneath the dunes can sometimes support limited agriculture. Agricultural land and artificial landscapes include cropland, town, villages and industrial sites.

The results of Basuony (2003) study show that the coastal and halophytic communities are inhabited by 21 mammalian species (100% of mammalian species recorded). The inland sand dunes come next with 10 species (48%) while only four species were recorded from the agricultural and artificial landscape habitat types (Table 13.3).

Table 13.3 **Mammals recorded from Zaranik protected area and their habitats: SF= mud flats and sand flats; SM= saltmarshes; CS= coastal sand dunes; IS= islets (after Basuony 2003)**

Species	Coastal and halophytic communities				Inland sand dunes	Agricultural land and artificial landscapes
	SF	SM	CS	IS		
Hemiechinus auritus			+			
Crocidura nana		+	+			+
Rhinolophus clivosus		+				
Asellia tridens		+				
Pipistrellus kuhlii			+			
Otonycteris hemprichii			+			
Lepus capensis			+	+		+
Gerbillus pyramidum			+	+	+	
Gerbillus andersoni	+	+	+	+	+	
Gerbillus gerbillus			+		+	
Dipodillus dasyurus			+	+	+	
Meriones crassus	+		+	+	+	
Meriones sacramenti	+		+			
Psammomys obesus		+		+		
Rattus rattus		+			+	+
Mus musculus		+	+	+	+	+
Jaculus orientalis	+	+		+		
Jaculus jaculus			+	+		
Vulpes zerda			+		+	
Felis silvestris		+	+		+	
Felis margarita		+	+		+	
21	**4**	**10**	**16**	**12**	**10**	**4**

The results also showed that although five species were restricted to only one habitat type, another five species were recorded in two habitat types. The

two rodents *Rattus ratttus* while was recorded from three habitat types in the area *Mus musculus* (Table13.3). Based on Morton and Davidson's-similarity index, similarity between the mammalian faunal assemblages of different habitats of the Bardawil area was generally low. The highest value of similarity index (0.65) was recorded between coastal and halophytic communities and inland sand dune agricultural and artificial landscape habitats. The lowest similarity index (0.28) was found between the mammalian faunal assemblages of coastal and halophytic communities, and agricultural and artificial landscape habitats. However, similarity between inland sand dune and agricultural and artificial landscapes mammalian assemblages was intermediate but also low (0.32).

13.3 SPECIES ACCOUNT

13.3.1 Rare Species

Two species representing two mammalian orders namely: Insectivora and Rodentia; (*Crocidura nana* and *Dipodillus dasyurus*) are rare. These species, in short period, may be entering the threatened species category.

13.3.1.1 Order Insectivora

Family Soricidae

***1- Crocidura nana* Dobson, 1890.**

Common names: Dwarf Shrew, Small White-toothed Shrew, *Ersa, Ersa El Shagar* الزباب القزم

Collection/observation localities: A small island in the eastern part of Lake Bardawil (N 31° 09′ 03, E 33° 27′ 17)

Distribution: Egypt and Eastern Africa from Sudan to Zimbabwe. In Egypt it has been recoded only from the Nile Delta (Osborn & Helmy 1980). The specimen collected during this survey represents the first record of this species in the Sinai Peninsula.

Habitats and ecology: Very little is known about this shrew (Osborn & Helmy, 1980). Specimens have been collected from under stones, bricks and clumps of earth in moist cultivated fields (Hoogstraal, 1962). It has also been found in canal banks, in dry wells, and under piles of grass, cotton, and corn stalks (Osborn & Helmy, 1980). The specimen collected during this study fell in a pitfall trap set for insects in a densely vegetated sandy area on an island at the eastern corner of Lake Bardawil. It is a nocturnal species and feeds on insects.

Status: Rare. The species appears common in the Nile Delta and possibly the Nile Valley. Nothing is known, however, about the status of this newly discovered population in northern Sinai.

Remarks: The presence of this species in northern Sinai, in such an atypical habitat is rather intriguing. The possibility of a relict status of this

population as Lake Bardawil is known to have been part of the Nile basin system in ancient time could provide a plausible explanation. The presence of the species in the Zaranik Nature Protectorate presents an invaluable opportunity for studying the virtually unknown biology and ecology of this species.

13.3.1.2 Order Rodentia

Family Crecitidae

2-Dipodillus dasyurus dasyurus **(Wagner, 1842).**

Common name: Wagner's Dipodil, جربيل فاجنار

Collection/observation localities: El-Khweinat Island of Lake Bardawil (N 31° 06′ 21, E 33° 24′ 28).

Distribution: *Dipodillus dasyurus* is widely distributed in Iraq, Arabia, Palestine, Yemen, Egypt and Sudan. In Egypt, the species is represented by the nominate subspecies *D. d. dasyurus* which inhabits Sinai Peninsula and the northern part of Eastern Desert.

Habitats and ecology: It inhabits both rocky and sandy habitats (Osborn and Helmy, 1980). At ZPA this species is found throughout the vegetated desert, but particularly in salt flats and among halophytic vegetation near lake shores and on islands. It is a nocturnal dipodil, feeding on halophytes as well as insects. Burrows are made in flat sandy areas under plants.

Status: Rare.

Remarks: Both Osborn and Helmy (1980) and Haim & Chernov (1974) reported *D. dasyurus* to be absent from littoral areas of Sinai; however, Saleh and Basuony (1998) recorded this species from coastal plains of Nabq and Abu-Gallum of Aqaba Gulf. In this study *Dipodillus dasyurus* was collected from the coastal area.

13.3.2 Noteworthy Species

Fourteen species of recorded mammals in Bardawil area and Zaranik Protectorate are noteworthy species as a result of abundance cultural, economic importance and interest species such as *Psammomys obesus* that also correlated with native halophytic plants. These species belong to four orders discussed below.

13.3.2.1 Order Insectivora

Family Erinaceidae

3-Hemiechinus auritus **(Gmelin, 1770).**

Common names: Long Eared Hedgehog, *Qunfid.* القنفذ طويل الأذنين

Collection/observation localities: Near the check point (N 31° 07 12, E 33° 28 40). Tracks were found throughout the vegetated areas of coastal plain at Zaranik.

Distribution: *H. auritus* has a range that extends from the coast of Libya and Egypt to Asia Minor, northern Arabia, southern former USSR, Iran, Pakistan, China, Turkistan and Mongolia. In Egypt, it is distributed along the Mediterranean coast, Nile Delta and Nile Valley south to Samalut and El-Faiyum. In Sinai this hedgehog has been collected once from El Arish (Osborn & Helmy 1980). However, the species appears to be rather common throughout the Mediterranean coastal desert of Sinai.

Habitats and ecology: It inhabits gardens, olive gardens, cultivated areas and more densely vegetated areas of the coastal desert. At the ZPA this hedgehog and its tracks were observed, it is a nocturnal species and feeds on insects (Osborn & Helmy, 1980) as well as lizards (Saleh and Basuony, 1998).

Status: Lower risk, least concern.

Remarks: The long-eared hedgehog appears to be much more widespread throughout northern Sinai than formerly believed. The taxonomic position of specimens from that area, however, is not clear (Osborn & Helmy 1980). *Hemiechinus auritus* from the Nile Valley has been placed under the subspecies a*egyptius* while populations occupying the Mediterranean coastal belt of the Western Desert and the western fringes of the Nile Delta have been described as *H. a. libycus*. Specimens from northern Sinai are generally much lighter than other Egyptian populations and have been tentatively placed under the subspecies *aegyptius*. The ubspecific status of the north Sinai is now under investigation.

13.3.2.2 Order Chiroptera

Several species of bats are known to occur in northern Sinai (Qumsiyeh 1985). The identity of these bats, however, could not be ascertained since we were not able to find any bat roosts within the boundaries of the protected area. The following is a brief account of the species that are most likely to be at least foraging in the Zaranik area.

Sub-Order Microchiroptera

Family Rhinolophidae

***4-Rhinolophus clivosus* Cretzschmar, 1828.**

Common names: Arabian Horseshoe Bat, الخفاش حدوة الفرس

Distribution: *R. clivosus* ranges from Algeria to Egypt and Cameron to South Africa in sub-Saharan Africa. In Egypt, it is known from Sinai and Eastern Desert.

Habitats: Roosts in old wells, caves and temples.

Status: Unknown.

Remarks: Wassif (1953) collected this species from El-Arish city as *R. acrotis*. Qumsiyeh (1985) recorded *R. clivosus* from the same locality.

Family Hipposideridae

***5-Asellia tridens* (Geoffory, 1813).**

Common name: Trident Leaf-nosed Bat. خفاش ثلاثي النتوءات

Distribution: *A. tridens* is found in North, West and East Africa and in Asia as far east as Pakistan. In Egypt, it is widespread in desert and semidesert regions.

Habitats and ecology: Dry caverns, dark ruins and underground irrigation channels. It is a colonial species. Its flight is low and swift being able to make rapid twists and turns (Harrison & Bates, 1991).

Status: Low risk, least concern.

Remarks: Hoogstraal (1962) and Qumsiyeh (1985) recorded this bat from El-Arish.

Family Vespertilionidae

***6-Pipistrellus kuhlii* (Kuhl, 1819).**

Common name: Kuhl's Pipistrelle. خفاش كول

Distribution: *P. kuhlii* is a very widely distributed bat with a range that extends from southern Europe to Pakistan and most of Africa; from Morocco to Egypt and south to South Africa. In Egypt, it is abundant around human populated areas in its northern parts.

Habitats and ecology: It is a colonial species that roosts in crevices in walls and roofs of building as well as in underground tunnels.

Status: Low risk, least concern.

Remarks: Wassif (1953) collected this bat from Maqdabah, 30 km south of El-Arish. Harrison & Bates (1991). reportsed one specimen from the Zaranik area

***7-Otonycteris hemprichi* Peters, 1859.**

Common name: Hemprich's Long-eared Bat. خفاش همبرش

Distribution: *O. hemprichii* is widely distributed in the desert zone from Morocco through to Egypt and east to Tadzhikistan, Afghanistan and Kashmir. In Egypt, it is widespread in all areas.

Habitats and ecology: This bat is adapted for life in extremely barren and arid areas, where it roosts in rock crevices.

Status: Low risk, least concern.

Remarks: Wassif (1953) collected this bat from the city of El-Arish.

13.3.2.3 Order Lagomorpha

Family Leporidae

***8-Lepus capensis sinaiticus* (Ehrenberg, 1833).**

Common names: Sinai Hare, *Arnab Gabali.* أرنب الكاب

Collection/observation localities: El-Flowsiat (N 31° 07′ 09, E 33° 26′ 02) and El-Matly Islands (N 31° 06′ 34, E 33° 26′ 22).

Habitats and ecology: This here inhabits vegetated deserts. Mostly nocturnal (particularly in summer months) spending the day in clumps of vegetation. Desert hares appear to feed on a great variety of plants. Among common plants in northern Sinai that are eaten by hares are *Retama raetam, Lycium sp*, and *Zygophyllum coccineum* (Osborn & Helmy 1980, Izhaki and Ne' eman 1997).

Status: Lower risk, least concern.

Remarks: Previous records of this hare in Sinai come from El-Quseima, Wadi Raha, Wadi Feiran, Wadi El-Sheikh, Saint Catherine Monastery, Gabal El-Maghara, Elwate El-Agramiya and Ras El-Naqab (Murray, 1912; Flower 1932, Wassif 1953, Setzer 1958b, Osborn & Helmy 1980, Saleh & Basuony 1998). The present records add northern Sinai to the known geographical range of this hare that now appears to cover the entire Peninsula.

13.3.2.4 Order Rodentia

Family Crecitidae

***9-Gerbillus pyramidum floweri* (Thomas 1919).**

Common names: Greater Egyptian Gerbil, *Demsy.* الدمسي

Collection/observation localities: El-Flosiat Island (N 31° 07′17, E 33° 26′ 01) and in the vicinity of visitor's building (N 31° 04′ 41, E 33° 27′ 56).

Distribution: *Gerbillus pyramidum* is widely distributed in North Africa, Sudan, Northern Chad, Niger, Mauritania and Palestine. In Egypt, it inhabits the Nile Valley and Delta, Western Desert, Eastern Desert and Sinai. *Gerbillus pyramidum floweri* has been recorded from several localities in both the northern Sinai and northern part of the Eastern Desert.

Habitats and ecology: It inhabits palm groves and areas near cultivation (Hoogstraal 1963) and in sand dunes of northern Sinai (Wassif 1953). At the ZPA this species is widespread in sandy areas with relatively dense vegetation. It is a nocturnal gerbil and feeds on plant seeds and leaves (Basuony 1993).

Status: Lower risk, least concern.

Remarks: Happold (1967) considered *G. pyramidum* to be better adapted to desert environment of the Sudan than *Jaculus jaculus.* The species is also reported from semi-stabilized dunes (Abramsky & Pinshow, 1989).

***10-Gerbillus andersoni bonhotei* (Thomas, 1919).**

Common names: Anderson's Gerbil, *Bayoudi.* جربيل اندرسون

Collection/observation localities: El-Flosiat Island (N 31° 09′ 10, E 33° 27′ 16) El-Matly Island (N 31° 06′ 34, E 33° 26′ 22) and Salma Islands (N 31° 04′ 22, E 33° 31′ 54).

Distribution: *Gerbillus andersoni* is distributed in Jordan, Egypt, Libya and Tunisia. In Egypt, it is recorded from the northern part of the country where three subspecies are recognized. *Gerbillus andersoni bonhotei* is the subspecies found in northern Sinai, where it has been recorded from the eastern part of that area. The specimens collected during this study somewhat extend the geographical range of the subspecies westward.

Habitats and ecology: It inhabits palm groves and sand dune areas and cultivated desert areas in northeaster Sinai (Osborn & Helmy 1980). Harrison (1975) describes it as being strictly psammophilous. However, it does not inhabit more harsh desert areas (Hoogstraal 1963). At the ZPA this species is found throughout the vegetated desert, including the islands. It is a nocturnal gerbil, feeding on plant material and insects. Burrows are made in flat sandy areas under vegetation.

Status: Lower risk, least concern.

Remarks: This subspecies was recorded only from northeastern Sinai (Flower 1932, Wassif 1953, Osborn & Helmy 1980).

***11-Gerbillus gerbillus asyutensis* Setzer, 1960.**
Common names: Lesser Gerbil, *Bayoudi.* البيوضي

Collection/observation localities: El-Flosiat Island (N 31° 09′ 10, E 33° 27′ 16) and in the vicinity of visitor's building (N 31° 04′ 41, E 33° 27′ 56).

Distribution: *Gerbillus gerbillus* is widely distributed in Libya, Palestine, Egypt, Sudan, and parts of Niger, Uganda, Mauritania, Chad, and Mali. In Egypt, it is the most common and widely distributed gerbil being found in all suitable habitats in the Western, Eastern Deserts and Sinai deserts. The subspecies *asyutensis* occurs in the Sinai Peninsula and the northern half of Eastern Desert.

Habitats and ecology: It inhabits palm groves, sand dunes and cultivated desert areas (Osborn & Helmy 1980). At the ZPA this species is found throughout the vegetated desert, including the islands. It is a nocturnal gerbil, feeding on seeds, roots and leaves of desert plants, as well as insects (Basuony 1993). Burrows are made in flat sandy areas rarely under plants.

Status: Lower risk, least concern.

Remarks: The study shows that this subspecies is widespread throughout Sinai. It has been previously recorded only from the Sinai coast of the Gulf of Suez and northeastern Sinai (Osborn and Helmy, 1980); however, Saleh and Basuony (1998) recorded it from numerous localities throughout the Peninsula.

***12-Meriones crassus crassus* Sundevall, 1842.**
Common names: Silky Jird, Sundevall's Jird, *Jarad.* جرد كراسوس

Collection/observation localities: El-Flosiat Island (N 31° 09′ 10, E 33° 27′ 16.

Habitats and ecology: It inhabits wadis and coastal areas of Sinai Peninsula where there is vegetation, human habitation or past activity (Osborn & Helmy 1980). At the ZPA this species is found throughout the vegetated desert, including the islands. It is both nocturnal and diurnal (depending on the season), feeding on seeds, roots and leaves of desert plants (Basuony 1993). Burrows are made in barren, stony, gravelly or flat sandy areas.

Status: Lower risk, least concern.

Remarks: Haim and Chernov (1974) presented a map showing the distribution range of *M. crassus* in Sinai. According to this map, the distribution of this Jird without giving specific collection localities covers almost the entire Peninsula. The material obtained during this study agrees with the description of this subspecies (Osborn & Helmy, 1980).

***13-Psammomys obesus terraesanctae* Thomas, 1902.**
Common names: Fat Sand rat, Jerdy, Jarada. الجرد- فأر الرمل

Collection/observation localities: El-Flosiat Island (N 31° 08′ 32, E 33° 28′ 39) and different sites with halophytes.

Distribution: *Psammomys obesus* is widely distributed throughout North Africa, Sudan, Arabia and Palestine. In Egypt, it is recorded in the Mediterranean coastal belt of the Western Desert south to Maghra Oasis, and east to the western fringes of the Nile Delta; the northern part of the Eastern Desert, including the Suez Canal area; and North Sinai. The subspecies *terraesanctae* occurs in northern Sinai and the northern part of the Eastern Desert.

Habitats and ecology: *Psammomys obesus* inhabits saline areas and salt marshes with stands of succulent halophytics such as *Halocnemon strobilaceum, Salicornia fruticosa* and *Anabasis articulata* of the study area. It is a colonial Strictly diurnal desert rodent. However, Atallah (1967) described some nocturnal activity of the sand rat in Jordan. Tunnels of a burrow system are seldom deeper than 0.5 m., but may be several meters in length. The number of openings 6-21 with an average of 11 (Osborn & Helmy 1980)

Status: Lower risk, least concern.

Remarks: This subspecies is relatively dark as compared with the other subspecies of Egypt.

Family Muridae

***14-Rattus rattus* (Linnaeus, 1758).**
Common names: House Rat, Black Rat, *Far, Gorz* جرد اسود

Collection/observation localities: Visitors' center of ZPA and adjacent areas (N 31° 04′ 41, E 33° 27′ 56)

Distribution: A cosmopolitan species. In Egypt, *Rattus rattus* is distributed in Nile Valley and Delta, coastal towns, certain oases in the Western Desert, northern and southern parts of the Eastern Desert, and the Suez Canal area. The present record represents the first record of this species in Sinai.

Habitats and ecology: It is commensal with man. Diurnal and nocturnal, and feeds on vegetables and seeds.

Status: Lower risk, least concern.

Remarks: The specimens collected during this study average smaller than those collected by both Osborn & Helmy (1980) and Harrison and Bates (1991).

***15-Mus musculus praetextus* (Brants, 1827).**
Common names: House Mouse, *Far, Sisi.* فأر المنزل

Collection/observation localities: Visitor center at ZPA and adjacent areas (N 31° 04′ 41, E 33° 27′ 56)

Distribution: A cosmopolitan species. In Egypt, *Mus musculus* is distributed in the Mediterranean coastal belt, Nile Valley and Delta and oases of Western Desert, Red Sea coastal towns, Suez Canal area, and the Sinai Peninsula. Both commensal and wild populations have been recorded throughout the country. In Sinai, *Mus musculus* has been recoded from El Arish, Oyun Musa, El Tur (Osborn & Helmy 1980) and the Gulf of Aqaba coast (Saleh & Basuony 1998).

Habitats and ecology: It inhabits houses, tents, grain stores, gardens and salty areas. It is a nocturnal species. Burrows are shallow and usually under shrubs.

Status: Lower risk, least concern.

Remarks: The color of the specimen is more buff when compared with the same species in other localities.

Family Dipodidae

***16-Jaculus jaculus schlueteri* (Nehring, 1901).**

Common names: Lesser Egyptian Jerboa, *Gerbouh*, اليربوع الحر

Collection/observation localities: El-Flosiyat Island of Lake Bardawil (N 31° 08′ 32, E 33° 28′ 39).

Habitats and ecology: Plains and wide sandy areas often near the vegetation. A strictly nocturnal species. Burrow dug in hard sand. Feeds on seeds, grasses and roots of plants.

Status: Lower risk, least concern.

Remarks: Wassif (1953) recorded this subspecies from El-Arish and Gebel Lehfan. However, Osborn & Helmy (1980) recorded it only from southwestern areas of Sinai.

13.3.3 Threatened Species

Four mammalian species recorded in ZPA are categorized locally and at national level as threatened species (IUCN 2000). These are a rodent species, *Jaculus orientalis* and three carnivore species namely: the Fennec Fox, *Vulpes zerda*, Wild Cat, *Felis silvestris* and Sand Cat, *Felis margarita*.

13.3.3.1 Order Rodentia

Family Dipodidae

***17-Jaculus orientalis* Erxleben, 1777.**

Common names: Greater Egyptian Jerboa, *Gerbouh*,اليربوع الكبير

Collection/observation localities: El-Flosiyat Island of Lake Bardawil (N 31° 08′ 32, E 33° 28′ 39). One specimen was observed in the late afternoon on the island. No specimens were captured, however, and the occurrence of the species in the area requires further verification.

Distribution: North Africa, eastward to Sinai Peninsula and Palestine. In Egypt, it has been recorded in the Mediterranean coastal belt of the Western Desert. In Sinai the species has been recorded only from Abu Rudeis area in southwestern Sinai. The one specimen recorded during this survey adds Northern Sinai Mediterranean coastal belt to the geographical range of this species.

Habitats and ecology: Seashore area, salt marshes and sandy areas. It is strictly nocturnal and become active at dusk. The burrow depth reaches to 2 meters and openings are closed when occupied. Feeds on sprouting vegetation.

Status: Vulnerable. Large numbers of this species are captured and exported each year. Depletion of some local population has been reported (Saleh, 2000).

Remarks: This species has not been previously recorded from the northern Sinai. Previous records of this Jerboa in Sinai come from southwestern part (Anderson 1902, Setzer 1958a, Hoogstraal 1963, Haim & Chernov 1974,Osborn & Helmy 1980).

13.3.3.2 Order Carnivora

Family Canidae

***18-Vulpes zerda* (Zimmermann, 1780).**

Common names: Fennec Fox, *Fanac.* الفنك

Collection/observation localities: Tracks of this fox were found throughout sandy areas of the protectorate, including Salma Island (N 31° 04′ 22, E 33° 31′54).

Distribution: Western Arabia, Sinai Peninsula, Egypt and northern Sudan west of the Nile River; thence westward across the Sahara into Mauritania. In Egypt, it occurs in sandy areas of the Western Desertas well as in several localities in the north and northwest Sinai.

Habitats and ecology: It is a strict inhabitant of sandy areas, nocturnal although it is occasionally seen outside during the day, particularly during winter. Burrows are made in sandy hillocks under vegetation.

Status: Vulnerable.

Remarks: Fresh fennec tracks were found at different localities during this survey, especially on sand dunes.

***19-Felis silvestris tristrami* (Pocock, 1944).**

Common names: Wild Cat, *Qut Gabali.* قط جبلي

Collection/observation localities: Tracks were observed throughout the area.

Distribution: *Felis silvestris* is widely distributed in Asia, Europe and Africa. In Egypt, it has been recorded from oases and the Mediterranean coastal belt of the Western Desert, the Nile Valley and Delta, and Sinai Peninsula. *F. s. tristrami* is the subspecies in Sinai where it has been recorded from a number of localities throughout the Peninsula (Osborn and Helmy, 1980; Saleh & Basuony, 1998),

Habitats and ecology: Rocky and semi-desert as well as vegetated sandy plain (Saleh & Basuony 1998). Nocturnal and feeds on hares, rodents, foxes and reptiles (Dorst 1970, Basuony 1998, Saleh & Basuony 1998).

Status: Vulnerable.

Remarks: This subspecies is recorded only from a few sites in the Peninsula as Wadi El-Arish, Abu-Gallum and Abu Dura mines by Flower

(1932) and Harrison (1968). The recent record of this animal was by Saleh & Basuony (1998) from Abu-Gallum, Gabal El-Maghara and Wadi Al-Arbaien. This recent record and that of the present study added northern and northwestern Sinai to the geographical range of this cat in Sinai.

20-*Felis margarita margarita* Loche, 1858.
Common names: Wild Cat, Sand Cat, *Qut El Rimal.* قط الرمال

Collection/observation localities: Tracks of this cat have been observed throughout sandy areas of ZPA.

Distribution: *Felis margarita* is thinly, but widely distributed in Morocco, Senegal, Algeria, Niger and Egypt in Africa; and northern Iran, Arabia, Turkestan and Baluchistan in Asia. In Egypt, it has been recorded from the Eastern Desert and the Sinai Peninsula. The nominate subspecies *F. m. margarita* is the subspecies occurring in the Sinai Peninsula (Saleh & Basuony 1998).

Habitats and ecology: Rocky and semi-desert areas as well as vegetated sandy plain (Saleh & Basuony 1998). It is a nocturnal cat that feeds on birds, rodents and reptiles (Osborn & Helmy 1980).

Status: Vulnerable.

Remarks: Saleh and Basuony (1998). recorded this subspecies only from Bir El Abd and Gebel El-Maghara. A photograph of an individual captured in Zaranik is on display at the Visitors' Center.

13. 4 SUMMARY

Five orders representing eleven families, sixteen genera and twenty one species of mammals were recorded in Bardawil region and Zaranik Protected Area during 2002. The long-eared hedgehog *Hemiechinus auritus* appeared to be much more widespread throughout northern Sinai than formerly believed. Fourteen species are Saharo-Sindian forms that have a wide distribution in the Sahara and southwestern Asia. Four species belong to the genera *Pipistrellus, Lepus, Rattus and Mus* are considered cosmopolitan with almost worldwide distribution. *Rhinolophus clivosus* and *Crocidura nana* are the only Afrotropical species .Pluriregional species, which have distribution in the Mediterranean and the Saharo-Sindian regions, are represented by *Felis silvestris* only.

The mammalian species of Bardawil area are distributed among a wide range of habitats. The coastal and halophytic communities are inhabited by 21 mammalian species. The inland sand dunes come next with 10 species, while only four species were recorded from the agricultural and artificial landscape habitat types.

Four mammalian species recorded in Zaranik Protectorate are categorized locally and at the national level as threatened species. These are a rodent

species, *Jaculus orientalis* and three carnivores namely: the Fennec Fox, *Vulpes zerda*, the Wild Cat, *Felis silvestris* and the Sand Cat, *Felis margarita*. Two species; *Crocidura nana* and *Dipodillus dasyurus* are rare. These species, in short period, may be entering the threatened species category; therefore, they need a management programme and continuous monitoring.

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13.6. PLATES OF MAMMALS (13.1 – 13.9)

(after Wassif 1995, Websites: www.animals.net & www.iucn.org)

Plate 13.1
Hemiechinus auritus
Rhinolophus clivosus

Plate 13.2
Asellia tridens
Pipistrellus kuhlii

Plate 13.3
Lepus capensis
Gerbillus pyramidum

Plate 13.4
Gerbillus andersoni
Gerbillus gerbillus

Plate 13.5
Meriones carssus
Psammomys obesus

Plate 13.6
Rattus rattus
Mus musculus

Plate 13.7
Jaculus orientalis
Jaculus jaculus

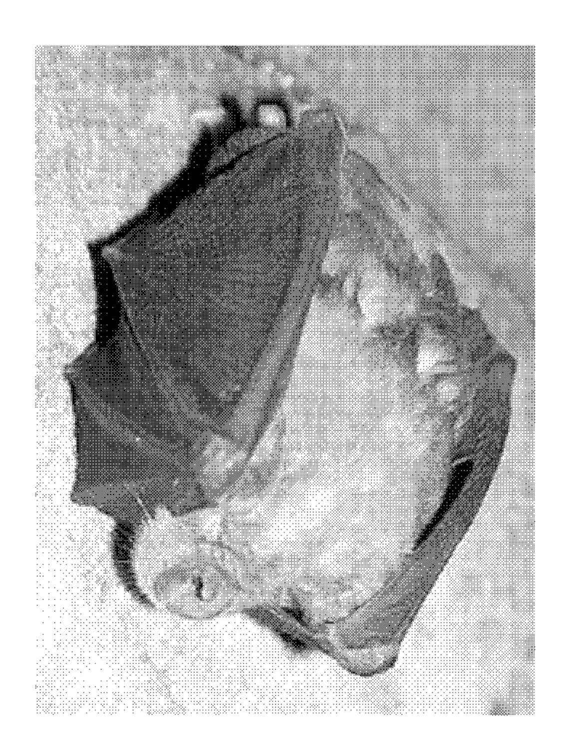
Plate 13.8
Vulpes zerda
Felis silvestris

Plate 13.9
Felis margarita

Plate 13.1



Hemiechinus auritus القنفد طويل الأذن



Rhinolophus clivosus الخفاش حدوة الفرس

Plate 13.2



Asellia tridens **خفاش ورقي الأنف**

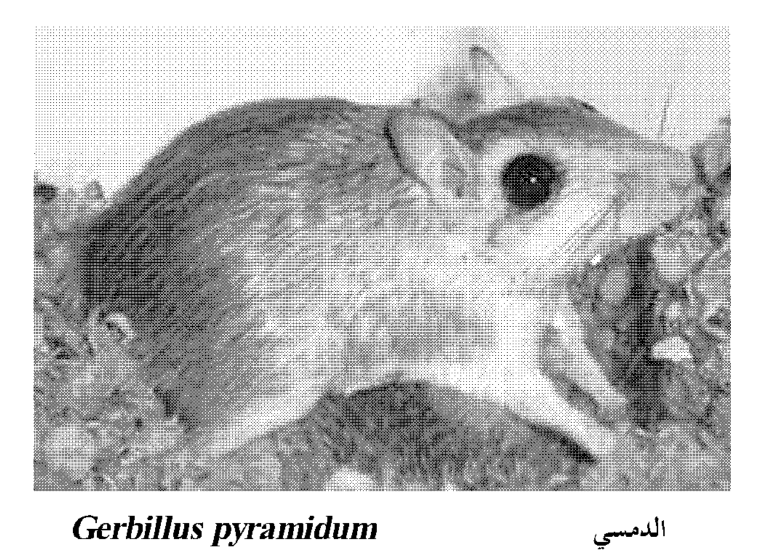


Pipistrellus kuhlii **خفاش كول**

Plate 13.3



Lepus **capensis** أرنب الكاب

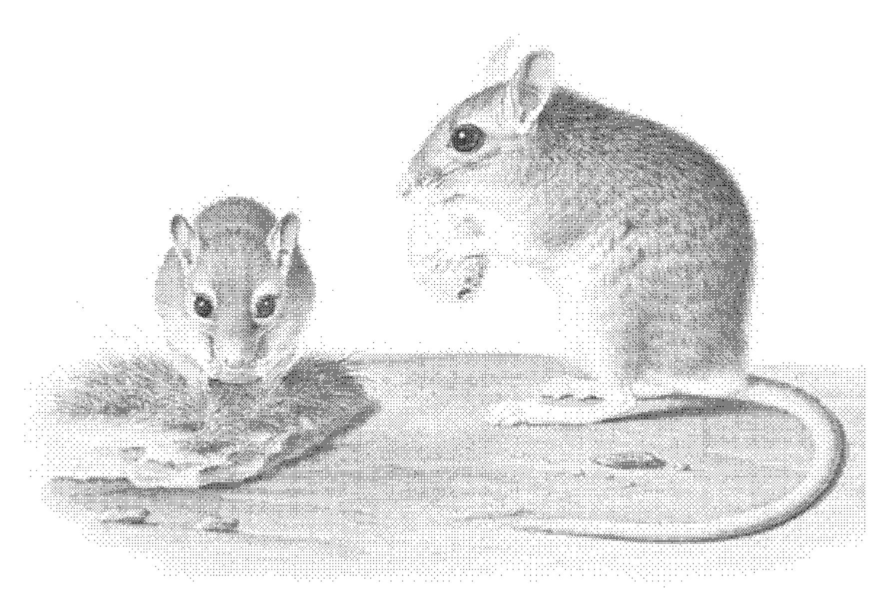


Gerbillus pyramidum الدمسي

Plate 13.4



Gerbillus andersoni جربيل اندرسون

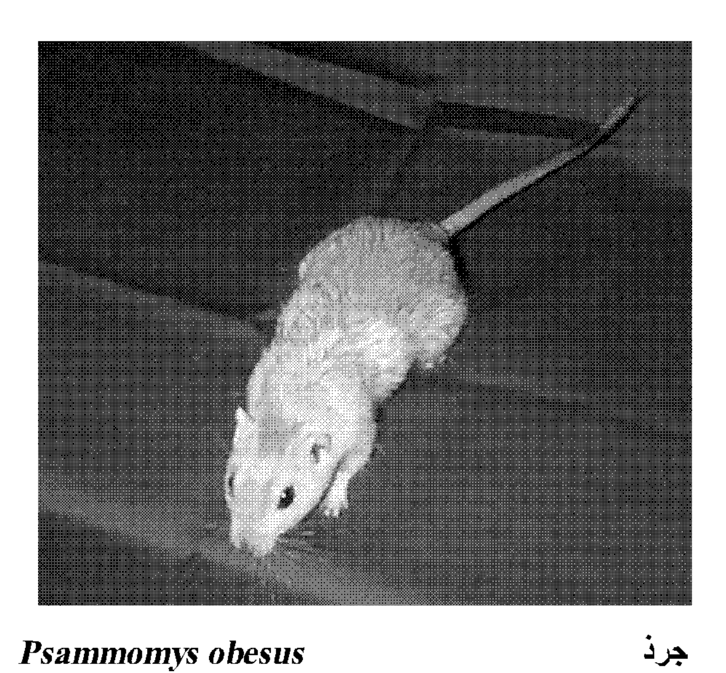


Gerbillus gerbillus البيوضي

Plate 13.5

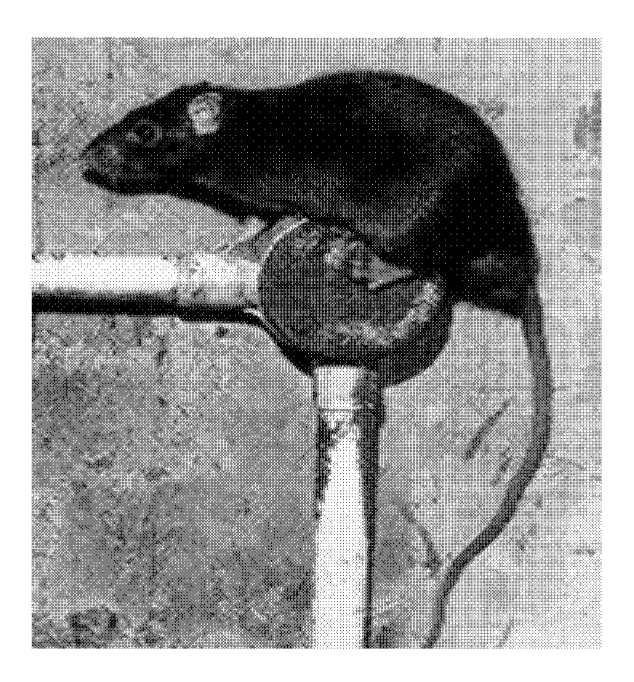


Meriones **carssus** مريونز كراسوس



Psammomys obesus جرذ

Plate 13.6

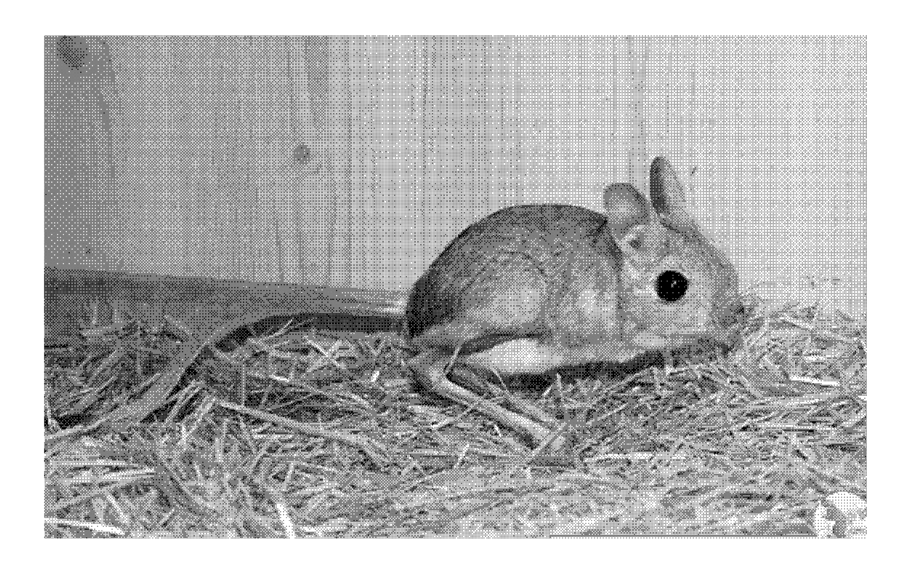


Rattus rattus جرذ أسود

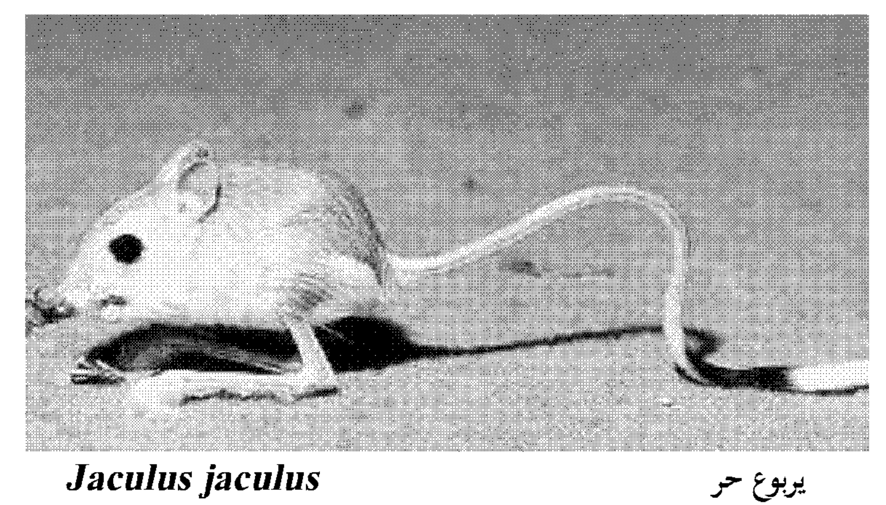


Mus musculus فأر المنزل

Plate 13.7

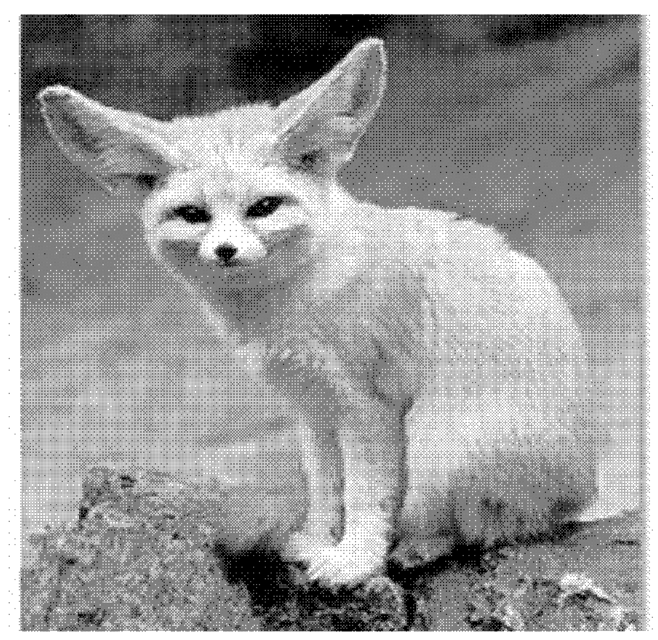


Jaculus orientalis القرفتي



Jaculus jaculus يربوع حر

Plate 13.8

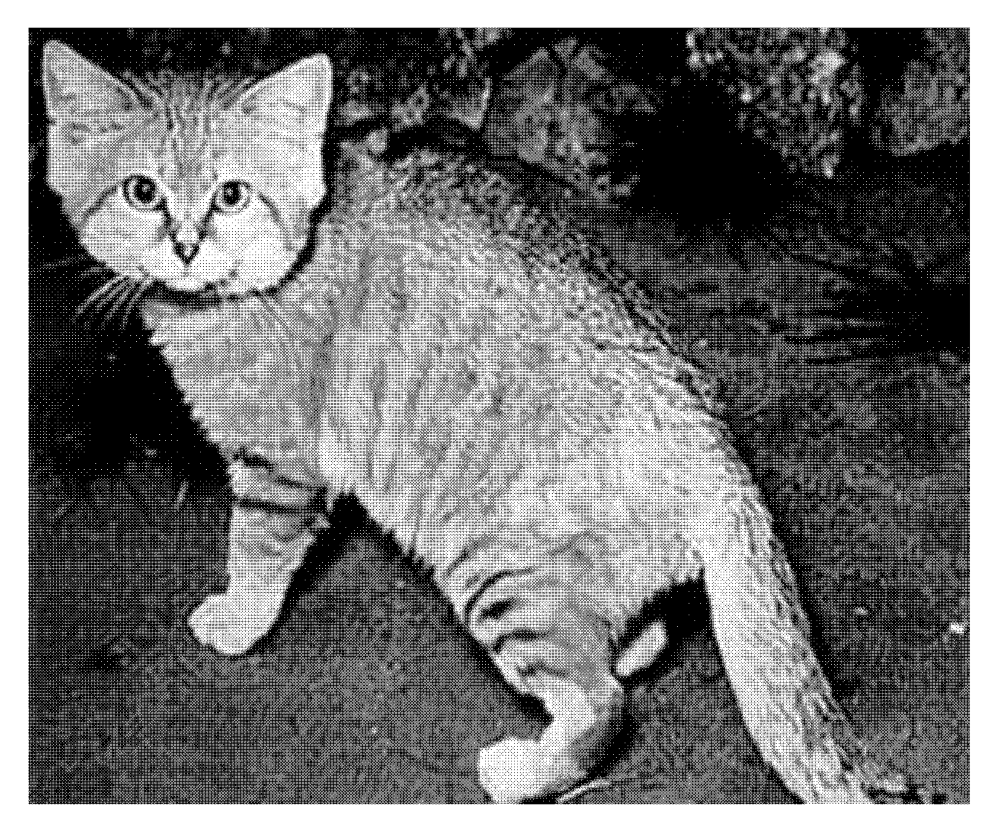


Vulpes zerda الفنك



Felis silvestris قط جبلي

Plate 13.9



Felis margarita قط الرمال

Chapter 14
Socioeconomic Features

Experience during recent decades asserted that efforts carried out to preserve natural protected areas could culminate with success when taking the human element into consideration, as well as attracting inhabitants of protected areas to effectively participate in plans undertaken for development and conservation of the natural environment of such areas. This needs to be based on raising awareness of inhabitants, and linking their direct everyday life interests and preserving the natural elements available in the protected areas; and requires study of the prevailing economic and social characteristics in protected areas. In this regard, Shaker *et al.* (2000) conducted a study on Bardawil Wetland and Zaranik protected area, aiming at identifying the prevailing economic, social and institutional characteristics in villages and different districts of the area, to introduce diagnostic analysis for human-environment interface and to identify the core problems faced by inhabitants to be taken into consideration in development of area planning.

14.1 ETHNOLOGIC MORPHOLOGY

Historically, El-Arish (the major city in North Sinai) has been the seat of government and a major service center for trading and merchants. With modern facilities and convenient location, it has attracted many residents. There were generations of inhabitants who have lived in the town, but many were not of Bedouin origin. A migration movement towards the urban centers (e.g. El-Arish and Bir El-Abd, El-Telul and El-Roda) occurred in North Sinai, especially as young and educated family members refuse to stay within the strong family boundaries and move to cities. Rail construction, road building, and lying of potable water pipes have attracted many local Bedouin tribe members to the work sites.

Settlements, mainly consisting of tribe members, were established along the Qantara - El Arish road, and the number of people who are moving into the existing settlements in date-grown areas has substantially increased. During

Israeli occupation, social groups were dismantled as people moved away from the villages. Some were exposed to modern agriculture and irrigation techniques, while they were working as agricultural labor. The period following the liberation of Sinai saw a slow movement back to settlements. Food aid was required to help re-establishing settlements. With further experimentation and practice of modern farming techniques, the early 1980's experienced large-scale movement in settlements to take up fishing, employment and education opportunities as well as farming. As a result, there were only a few nomads, mainly in Rabaa, Om Aqba and Katya still practicing the traditional semi-nomadic lifestyle.

The origin of the inhabitants of Abu Hosein and Abu Zatun include 82% of the Suwarka tribe; while the rest belongs to the Garawan tribe. They inhabited the area a long time and the people do not remember their old origin, so they consider this area as their homeland.

14.2 DEMOGRAPHIC DEVELOPMENT

There are no other regions in Egypt or in the Middle East that has been influenced by so many various cultures. Throughout history, North Sinai has been a cultural land bridge between Asia and Africa. Numerous armies (more than 40) passed, westward or eastwards, through Sinai and a continuous cultural intercourse took place.

The majority of North Sinai's population is mainly of Bedouin origin, although many urban inhabitants are non-Bedouin. The greatest number of Bedouin in Egypt lives in Sinai. The Bedouin still practice the traditional lifestyle, which is adapted to the desert environment. Some of them have settled in rural communities (Table 14.2).

Table 14.1. **Population of North Sinai (Anonymous 1997& 2003).**

Year	**1986**	**1996**	**1999**	**2003**
Population Number	**171505**	**252750**	**283643**	**302 000**
Density of Total Area/ km^2	**6.2**	**9**	**10**	**11**
Density of Inhabited Area (ind. /km^2)	**1159**	**1373**	**1542**	**—**
Growth Rate (%)	**4**	**4**	**2. 6**	**2. 6**

During the last two decades, there was a migration movement towards the cities in North Sinai, especially young and educated family members who refused to stay within the strong family boundaries and moved to the urban centers (e.g. El-Aris, Bir El-Abd, El-Telul and El-Roda). The reasons for that migration into urban areas are:

1. scarcity of rain during the last decades (unsuitable climate),
2. unavailability of residence for them,
3. lack of medical, educational and other services (lack of infrastructure),

4. insufficiency of natural pasture,
5. high prices of dry and concentrated fodder,
6. income opportunities and stability in the urban area.

Table 14.2. **Population distribution in North Sinai Governorate (Anonymous 1997 & 2000).**

District	1986	1996	1999
Urban Areas	**105581**	**147137**	**165507**
Rural Areas	**65924**	**105023**	**118137**
Total	**171505**	**252160**	**283644**

14.2.1 Communities and Villages

Administratively, Bardawil area lies in the two administrative districts; El-Arish and Bir El-Abd. Both districts are in contrast to each other; while El-Arish is the capital of the North Sinai Governorate, an urban center; Bir El-Abd is a rural center. El-Arish is divided administratively into four suburbans, four rural units and 24 Bedouin communities. Bir El-Abd administratively is one municipality with 22 rural units and 90 Bedouin communities (Tables 14.3 & 14.4).

Table 14.3. **Population distribution in the two districts; El-Arish and Bir El-Abd (Anonymous 1997).**

District	1986		1996		1999	
	Urban	Rural	Urban	Rural	Urban	Rural
El-Arish	67638	--	98472	2010	110767	2261
Bir El- Abd	4778	22611	8177	30936	9198	34799
Total	72416	22611	106649	32946	119965	337060

Table 14.4. **Population density and growth rate of the two districts (density = ind. / km^2) (Anonymous 1997).**

District	Population Number	Total Area in km^2	Density of Total Area per km^2	Density per inhabited Area	Yearly Growth Rate
El-Arish	**100447**	**762**	**131.8**	**2391.6**	**2.372 %**
Bir El-Abd	**39114**	**3857**	**10.1**	**1029.3**	**3.604 %**
North Sinai Governorate	**273000**	**27564**	**9.9**	**196**	**2.36 %**

The population communities in the villages are:

Sebieka village, with around 320 persons, lies directly on Quantara – El- Arish road; there is water available but no electricity and no schools.

Abu Madi village, with 410 persons, no infrastructure (e.g. water, electricity, schools).

Fishermen' huts, about 32 families, living without infrastructure during the fishing season, from May until the end of December; even during the fishing season they are not allowed to stay over the weekend. (Thursdays and Fridays).
Abu Hosein village, with 600 persons, has water, electricity and a mosque but no school.
Awlad Sokeer community, with 50 persons, no infrastructure nor services.
Abu Zatun community, with 700 persons, no infrastructure nor services.

Around the Zaranik area, from the east to the west, Midan village lies at km 26, Sebika community at km 35, Mazar village at km 41 and Elrodah at km 47. There are some populations around the Zaranik Protectorate like El-Midan with a population of 350 persons, Mazar around 500 persons and El Rodah 500 – 550 persons, which gives a total of 1,400–1,450 persons who live in immediate neighborhood of the Protectorate. These growing populations, neighboring the site, could be of influence in the future, especially Mazar, because a great number of its population practices some economic activities inside the protected area, such as fishing, hunting birds and pasturing. Moreover, some of the Zaranik population benefit from the existing public services available in Mazar village such as education and health.

14.2.2 General Characteristics of the Local Population

To know the life style and general characteristics of local inhabitants, Shaker *et al.* (2000) applied two approaches for studying this aspect; the first is the group discussion, where the chief of the tribe or one of the elders calls a group meeting with various persons representing the different economic activity groups in the village. The second approach depended on personal interviews with help of a questionnaire designed to cover all the socioeconomic characteristics of the inhabitants.

Family Size. The average family size amounted to 8 persons, which exceeds the national average of 4 - 5 persons. It indicates that the growth rate is high in the local communities. This may be attributed, on one hand, to polygamy among the Bedouin groups, and on the other hand, to their cultural resentment to family planning and birth control.

Average Age. The average age is 70.7 years. It is worthy to mention that purity of natural environment, absence of pollution, in addition to the improvement of medical awareness, are the main factors in raising the average age of the inhabitants.

Type of Family. It has been revealed that over 50% of the inhabitants live in extended families. After the sons' marriage, they continue to live with their parents in the same household. However, nowadays it is common for anyone to separate from the extended family and live in a nuclear family.

14.3 SOCIAL CHARACTERISTICS

Social groupings in Sinai are based on tribal affiliations. Members of clans are family up to the 5th generation. Clans make up tribes, which are above the 5th generation. There are 12 identified tribes in the region. They are among the oldest dwellings in Sinai. Each tribe may comprise 500 to 1,200 persons. The main tribes in Northern Sinai are Al Sawarka, Al Rahilat, Al Massaeed and Arab Qatbah. There is a strong local cultural consciousness under the Bedouin tribes in Sinai, which is reflected in the preservation of values and traditions and established the customary law, which is still applied with the consent of the Egyptian administration. There is a growing official recognition of the uniqueness of the cultural and tribal diversity of North Sinai. This has led to founding of an organization for the preservation of cultural heritage, an ethnographic museum, and various publications on specific aspects of Bedouin culture (e.g. customary law) and others.

14.3.1 Education

Mixed primary schools are found in most villages, while secondary schools, and technical institutions that are located in Bir El-Abd and El-Arish. Education is widely valued in the community; the literacy level is shown in Table 14.5. However there are many problems; the resources given to schools remain low and truancy levels are high due to the participation of children in income generating activities. There is a high proportion of graduates in some of villages (the Neguila village has 80 graduates out of the population of 4,000) as many of the tribal Bedouin completed higher education during the Israeli occupation, when they were relocated to mainland Egypt (Table14.6).

***Table 14.5.* Population's educational status in person number and percentage (over 10 years old) (Anonymous 1997 & 1999).**

Year	1986		1996		1999	
	Persons	%	Persons	%	Persons	%
Illiterate	59924	48.8	65011	35.8	56277	27.6
Can read and write	30816	25.1	45756	25.2	68320	33.4
Literate	32050	26.1	70718	39	79548	39
Total	122790	100	181485	100	204145	100

14.3.2 Customary and Civil Law

Customary law is a distinctive feature of legislation in North Sinai. It is an unwritten law enforced by meetings of tribal or clan heads and elders. Politically, the tribal sheikhs (or heads) make all-important decisions regarding tribal affairs, as do clan heads in regards to clan affairs. Both would be likely to be judges in customary law.

District	PRIMARY 0SCHOOL	PREPARATORY	SECONDARY	PEDAGOGIC SCHOOL

	Vocations	Classes	Students	Vocations	Classes	Students	Vocations	Classes	Students	Vocations	Classes	Students
El-Arish	8	44	841	3	12	327	2	16	185	1	5	85
Bir El-Abd	10	55	720	14	42	455	4	19	162	--	--	--
Total	18	99	1561	17	54	782	6	35	347	1	5	85

***Table 14.6.* Educational services in both districts (Anonymous 2000).**

***Table 14.7.* Medical services in both districts (Anonymous 2000).**

District	Hospitals			Surgery Rooms	Med. Unit	Beds	Doc/per Hosp.	Nur -Ses	Med. Office	Ambu-lance Unit	Ambul. Car
	Gen	Center	Rurl								
El-Arish	1	--	--	5	6	211	58	154	4	2	13
Bir El-Abd	--	1	--	2	13	40	20	19	1	3	1
Total	1	1	--	7	19	251	78	173	5	5	14

A meeting may be called to discuss general tribe or clan matters or to sit at the "magad" (formal meeting place) for judgment of cases. The tribal elders (judges) are men considered to be of high moral integrity, wisdom and objectivity. Each tribe specializes in an area of customary law to judge in specific disputes; as land ownership, crime and religion. In case of marriage, it occurs within the clan and tribe. For women to marry outside the tribe, would means forfeit of grazing and land rights. Inheritance follows general Islamic laws of two shares for the man and one for the women. Inheritance rights especially to the land are usually settled through customary law.

In 1911, the state gave formal recognition to the role of 'desert laws customs and traditions'. By 1917, articles in Law 15 of Desert Administration Act gave further recognition to the validity of customary law practices. In 1949, civil legislation was imposed which gave the civil law predominance in judicial decisions, but if no applicable legislation exists, the judge may rule in accordance with custom. If custom cannot provide the answer, then he may turn to Islamic "sharii'a" (religious law). These attempts to integrate civil law with customary law were largely ignored by the local Bedouin tribes in the North Sinai. This is due to the continued wide practice of customary law and its general success in social control. In 1980, North Sinai Governorate gave power and recognition to customary law committees (under Law 569).

14.3.3 Land Ownership and Water Right

Existing customary law collides with civil law at the subject of land proprietorship, because Bedouins rely on rainfed agriculture, which depends mainly on rainfall. They do not have a fixed permanent water source as in traditional agriculture. They even move to places from sites where moving sand

dunes cover earlier cultivated plots, and when rainfall is enough for cultivating some of their seasonal traditional crops.

In civil law, North Sinai is classified as a desert Governorate and all the desert land is property of the Egyptian government; any use for development needs prior approval from the Ministry of Land Reclamation. Law number 148 relates to land and water rights. It provides recognition of original land ownership and for compensation, under certain conditions, of land whose expropriation may be necessary. However, on definition of "certain conditions" Article 2 of Law 148 states that only legally used or cultivated desert land is considered private property. The conditions for proprietorship being:

1. Legal title of land (as per Law 124, 1958).
2. Desert land dug or reclaimed or cultivated for at least one full year before issue of Law 124. No land or part of land, under rainfed irrigation will be considered as reclaimed.
3. Any reclaimed or cultivated desert land, is effectively and continuously farmed, provided with a permanent water source and falls within the state plan of reclamation.

In 1987, the North Sinai Governorate issued a decree offering land titles to anybody in the region who cultivated the land continuously for three years. However, this is not feasible to most of the poor Bedouins, as they have to dig a well to have a fixed water source, which is very costly and often covered by moving sand. On the other hand, many of their plots are sand and sand dunes, which are not suitable for the traditional agriculture. Therefore, what civil law demands, as a prerequisite for offering a land title are almost impossible to be fulfilled by the Bedouins. Although, a Registration Committee composed of government and non-government members was established in El-Arish to facilitate evaluation and approval of land titles. However, registration has so far been largely unsuccessful because of the administration process (registration can take up to six months). As customary law covers land ownership, there is no compelling reason for the tribe members to formally register the land.

14.3.4 Social Organization

The local Bedouin Sawarka and Akharsa tribes have historically tribal bindings and informal relations, and their main economic (cash) product came through fishing. They were involved in fishing in the lake for a long period. However, after liberation and the consequent settlements of large numbers of other tribes, fishing was taken up as a major activity, particularly by those from the villages of Selmana, El Telul and the town of Bir El-Abd. This has led to the creation of five fishing cooperatives, which are now mainly controlled by the Dawaghra tribe. The cooperatives employ 3,200 fishermen and there are some 1,094 boats in the area. Their income fluctuates according to the fish catch.

These fishermen are members of five big fishermen cooperatives, El –Arish, El-Salam, October, El-Bardawil and El-Sahel. The 30 fishermen operating in the Zaranik lagoon are members of El-Arish fishermen cooperative. The cooperatives offer members the following services:

- Marketing their fish catch,
- Installments payment for their fishing gear and equipment,
- Facilitate health services for the members,
- Present juridical backing for members if needed,
- Help members to obtain license and fishing permits.
- Providing insurance for the members and help them to pay their debts (loans).

14.4 ACTIVITIES AND IMPACTS

The land use systems and the economic activities in Bardawil Lagoon area are closely linked to the physiographic units. A low population density characterizes the region west of El-Arish. The population is living mainly in the coastal zone. Accordingly, fishery is quite common in this part of the Governorate. Lake Bardawil forms an important marine habitat. Rainfed agriculture is common and is an important economic activity. Pasturing causes extensive grazing by camels, sheep and goats.

Moreover, there is some irrigated agriculture in the district; the irrigation water is often illegally obtained from the Nile water pipeline (which provides the coastal zone with fresh water as far as El-Arish). Crops are mainly vegetables. Another source of water is the shallow ground water that is used for irrigation of watermelon, among others.

14.4.1 Agriculture

The agricultural production is depended on the sufficient winter rains. The cropping pattern comprises watermelon, cantaloupe, grapes, barely, tomatoes, dates, figs and olives. In the village of El-Mazar for example, the main crops are the date palms. Each family owns approximately 200 - 300 palms with a productivity of about 100 kg dates each per season. Watermelon and a little barley are grown between the sand dunes in the southern parts of Lake Bardawil where water is available.

There are two types of agricultural activities in the North Sinai region, the traditional and the modern farming method. The traditional method, in rainfed catchment's areas, where wheat, corn and barley crops are grown. These crops depend on good rainfall during the winter months to sustain a high yield. In summer, watermelon is usually grown. During the season, these traditional crops do not require much labor, except in land preparation and seed planting.

Of more significance are activities around the date collection at the end of summer (August - September). Date palms have an historic and cultural significance to the Bedouin tribes. Palm beaches were the symbol of North Sinai, even locations and expansion of some villages are a direct result of clusters of date palms. Over the last five years, a decrease in the amount of date palms in the area was noted; where in 1986, 9,470 Feddan of date palm were present; in 1990 only 6,723 Feddan were left, and in 1995 a further decrease of 2,314 Feddan, as a result of this, only 90,774 palm trees are left (Anonymous 1995).

The date palm is still an important source of food and income. Goats are fed on them and date palm by-products are used for housing construction, weaving and handicraft production. It is stated that the average nuclear family has three trees, while an average household owns 10 trees of which 6 are devoted purely for (date) food collection. A single palm tree can be used to earn L.E. 60 a season for the dates and even more if the dates are stored and sold off-season (EuroConsult 1992).

Modern agriculture method; small-scale drip irrigation agriculture has developed substantially over the last ten years. The technique was first introduced during the Israeli occupation in the Sheikh Zewaayed and Wadi El-Arish areas. Further experimentation and practice has developed the technique and it is now a popular and important economic activity. A total of 10,209 Feddan were reported in 1988 using modern methods, of which about 5,372 Feddan are in the project area. This may have substantially increased over the last three years with large-scale land reclamation activities (El- Salam Canal) particularly in Bir El- Abd district. Vegetables and fruits including tomatoes, cucumbers, melons, watermelons and fig, as well as olive trees are grown. The fresh fruits and vegetables are cultivated in off-season of the Delta, so these cash crops usually get very good returns. Yet, costs are substantial up to L.E. 30,000 per Feddan, high salinity levels in water is a high-risk enterprise. Building up of high salinity in the soil means that crop patterns must be carefully managed. Fruits or vegetables (usually melon or tomato) can be grown for one year, after which the land must then be left fallow for two years or replaced by olive or fig trees, which take five to six years to yield. This land use pattern has created a need to continually seek new land for reclamation and consequently introduced changes to land ownership and practices. With high-income returns available from the land, it is noted that in the more established agriculture regions (e.g. Qatia), there is a form of private rental, mainly confined within the clan, rent may reach L.E. 300 per Feddan per year, but for outsiders rent may be L.E. 500 per Feddan per year. However, the renting period is only for one year as the planting of trees entitles the tenant to claim the land under customary and civil law. The owner, as a result, only allows fruit and vegetable crops to be grown on his land.

Table 14.8. **Population data of both districts and their agricultural area (Anonymous 1997).**

District	% Arable Land of the Governorate	Arable Land in Feddan	Yearly Growth Rate (%)	Rural Areas	Urban Areas	Population Number
El-Arish	4.23	23525	2.372	2000	98447	100447
Bir El-Abd	12.17	16640	3.604	30935	179	39114
Total	16.4	40165	3	32935	106626	139561

Table 14.9. **Distribution of arable and fallow lands in the two districts (Anonymous 2000).**

District	El-Arish	Bir El-Abd	Total
Total Area (Feddan)	181356	917966	1099322
Agricultural Area (Feddan	13938	16865	30803
Reclamation Areas (Feddan	120000	303179	423179
Non Arable Areas (Feddan	24334	595431	619765
Number of Villages	4	22	26
Number of Agr. Cooperatives	8	14	22

The major crop production in the two districts are fruits (dates, olives, almonds, figs, peaches and pomegranate) and other crops like barley, wheat, water melons, tomatoes, some other vegetables and fodder plants for their animals (Table14.10).

Table 14.10. **Distribution of crop areas in Feddan in El-Arish and Bir El-Abd 1992/93 (Anonymous 1994).**

District	Field crops	Vegetables & Fruits	Orchards	Medicinal & Essence Herbs
El-Arish	34000	1950	10930	100
Bir El-Abd	7000	650	5846	130
Total	41000	2600	16776	230

Labor requirements are met mainly within the household and extended family, although during cultivation, additional help would be sought from clan members and outsiders, if required. It is estimated that it requires only one person per Feddan to fulfill the labor requirements for modern farming with fluctuations depending on type of crop and time of the year.

The role of women in agriculture is significant, as many are not only involved in the cultivation period but participate through the whole process, especially if the male head is employed in other activities or is reclaiming new land. Some women are further increasing their role in maintaining the head of drip pipes and dealing with the often-temperamental diesel well pumps.

Children are also used extensively in the cultivation of crops, generally for weeding and spraying of pesticides. There are case examples of young girls in the villages being hired directly by farmers for this purpose.

Table 14.11. **Total Size of arable land and Reclaimable land (Anonymous 1999).**

Year	1996	1999
Arable Land (Feddan)	310000	310000
ReclaimableLand (Feddan)	2619085	2638000
Total (Feddan)	2929085	2948000

Most of inhabitants use manure that is domestically produced to avoid using chemical fertilizers. The majority use seeds from their own production. This indicates the absence of extension services and agricultural cooperatives that usually supply the agricultural sector with high yield variety of seeds. They depend on merchants to obtain pesticides for controlling rats and jackals, which attack the crops. Also, it has been observed that the local inhabitants depend on certain herbs to prevent health problems. They usually collect these herbs, and recently they are trying to grow them to raise their family income. In general, the problems facing the agricultural production are:

- Drought phenomenon,
- Difficulty in reaching their agricultural plots,
- Moving sand dunes,
- High cost of production requirements and low return for their products,
- Infection of crops by pest vermins that leads to loss of income.

14.4.2 Pasturing

Ownership of camels and size of goat and sheep flocks traditionally assess wealth of individual Bedouin tribe members. Today, the economic reliance on livestock is waning. While they are still important in the economy of tribes, the livestock and grazing practices have been superseded by agricultural activities.

Camels are very important in Bedouin custom as a means of assessing status. The male members of the tribes practice grazing of camels, as it often requires many days out in the remote grazing areas. Camels are still used for transportation in the collection of dates in the remote inaccessible areas. The Bedouin tribes in the western area (Rabaa, Om Aqba and Katya) and central regions of Sinai, which are still essentially semi-nomadic, continue to depend on camels as a source of wealth and income. In general, however, camel rearing, particularly in the settled regions, has declined rapidly as cars and small trucks have replaced their practical use.

In nomadic life, large herds of 40 - 60 goats and sheep were common but the move to settlement has reduced herds significantly. Sheep can be sold for L.E. 900, about three times the price of goats. The grazing and herding of goats and sheep is exclusively the role of women, mostly the younger unmarried girls or the elder women.

As agriculture intensifies, livestock are being kept in corrals or yards in order to stop them destroying the crops. Thus, there is increasing reliance on fodder and feed, which are expensive. The overall costs and inconvenience of keeping livestock is a major factor in the reduction of herds. The most important problems related to pasturing activities are:

1. Shortage of dry fodder,
2. Limited areas for pasturing,
3. Absence of veterinarian care.

14.4.3 Fishing

Fishing gained significance for the Lake Bardawil. Although it is considered to be one of the best quality fishing areas in Egypt, its production was accounting to about 3534 tons and 0.7 % of the national fish production in 2005 (GAFRD 2005).

The local Bedouin Sawarka and Akharsa tribes have historically been involved in fishing of the lake. However, after liberation and the consequent settlements of large numbers of other tribes, fishing was taken up as a major activity, particularly by those from the villages of Selmana, El Telul and the town of Bir El-Abd. This has led to the creation of five fishing cooperatives, which are now mainly controlled by the Dawaghra tribe. The cooperatives embrace 3,200 fishermen and there are some 1,094 boats in the area. In Zaranik Lagoon, there are about 30 fishermen with 13 small poorly equipped boats.

The economic situation of fishermen makes it more difficult to gain their whole income out of the amount they catch. From January until March, fishing is forbidden inside the whole Bardawil Lagoon. The lake needs time to recover its fish population. In this time, the fishermen village is not occupied.

Fishing productivity

Table 14.12 shows the fish productivity per Feddan of lake Bardawil. It reached its maximum of about 2,763 tons in 1990, then dropped to 1,617 tons in 1992, but increased once more to 2,210 tons in 1993. This fluctuation in production could be because of the variations of water salinity, due to the inefficiency of the inlets between the sea and the lake (Barania 1994). The productivity (kg/Feddan) ranged from 9.7 kg in 1994 to 24.34 kg in 1999. It is clear that productivity per Feddan fluctuated over the years based on the change in gross production of fish and the water area of the lake.

Income

Fishermen depend on the boat productivity (the amount of caught fish). New nets and the payments for houses take up to one third of the income. Another third is allocated to the motorboat itself, the owner of the boat and other fishermen that are working with them. The rate of return on capital invested in fishing has been estimated for trammel nets and Verenda nets as

shown in Table 14.13 .Rates differ from 9.1% for trammel nets up to 15.7% for Verenda nets. In comparison with the opportunity cost of capital, it became clear that trammel nets is economically not feasible, but the Verenda nets proved to be economically feasible, and more efficient than the trammel method.

Table 14.12. **Fish production and productivity of Lake Bardawil during 1988-2005.**

Year	Gross Production (1000 Tons)	Area (1000 Feddan)	Number of Fishermen	Productivity	
				Kg/ Feddan	Ton/ fisherman
1988	1.7	165	2412	10.30	0.705
1989	2.3	165	2874	13.94	0.800
1990	3.0	165	3678	18.18	0.816
1991	3.0	165	3708	18.18	0.809
1992	1.8	165	3879	10.91	0.464
1993	2.2	165	3950	13.33	0.557
1994	1.6	165	3950	9.70	0.405
1995	2.2	160	3950	13.75	0.557
1996	1.6	160	3950	10.00	0.405
1997	2.2	160	3950	13.75	0.557
1998	1.9	160	3950	11.88	0.481
1999	3.9	160	3950	24.38	0.987
2000	3.3	160	3950	20.6	0.835
2001	3.1	160	3950	19.6	0.796
2002	3.1	160	3950	19.4	0.784
2003	3.3	160	3950	20.6	0.830
2004	2.2	160	3950	13.9	0.563
2005	3.5	160	3950	21.4	0.886

14.4.4 Bird Catching (Hunting)

Quail hunting is a traditional activity of the Bedouins of North Sinai. In the past, quail netters were mainly farmers and fishermen. Today, because of the rapidly changing demography of the region, individuals with a variety of occupations practice quail catching. For example, quail netters in the area between Zaranik and El-Arish included a truck driver, civil servant, tax inspector and teacher. Most catchers usually come from the nearest urban center between El-Arish and Zaranik. The majority of them come from El-Arish, while those stationed along the sand bar of Lake Bardawil are mostly from Bir El-Abd and other smaller villages.

An estimation of total quail catch is based on a sample of four catchers, comprising a total length of nets of 1,935 m, located along the stretch of beach between El-Arish and Zaranik. During 1990 season, every km of trammel net caught an average of 25.4 quails every day, or a daily average total of 4,550 Quails from the 179 km of nets, producing a grand total of 20500 quails in a 45 day season throughout North Sinai (Shaker *et al.* 2000)

Table 14.13. **Rate of return on investment in fishing in Lake Bardawil in 1999 (Shaker *et al.* 2000)**

Item	Trammel Nets	Verenda Nets
Capital Costs:		
Fishing Boats	**4000**	**18000**
Motors	**8000**	**16000**
Fishing Nets	**10000**	**40000**
Total Capital Costs	**22000**	**74000**
Fishing Period (Days)	**150**	**150**
Operating Costs		
Depreciation and Maintenance		
Fishing Boats	**611**	**2749**
Motors	**1222**	**2444**
Fishing Nets	**2555**	**10219**
Wages	**7445**	**52018**
Fuel & Oils	**2500**	**6000**
Fish Fodder	**1500**	**8000**
Opportunity Cost for the Owner as Manager	**1500**	**12000**
Miscellaneous	**3000**	**12000**
Total Operating Costs	**20333**	**105430**
Total Return	**22334**	**117040**
Net return	**2001**	**11600**
Rate of return on capital	**9.1 %**	**15.69 %**

A quail catcher's gross income (from quail catching) during the 1990 season was L.E. 1,250. Catchers renting their catching space by an average of L.E. 300 per season. Living expenses are reduced to their minimum in the desolate conditions of the North Sinai coast. However, a family of four or five individuals would spend at least L.E. 200 per season for food and other expenses. Thus, a generous estimate of the average net profit per catcher for the 1990 season ranges between L.E. 1,050 and L.E. 750 (for those renting their catching space). Quail catchers also consume a considerable amount of their catch, or give it away to friends and relatives (up to 16% has been calculated in one case).

Owners, who rent out their land for others to catch birds, benefit as well. Depending on the location and sea front length of their land, they may get L.E. 150 - 400 or even more per season. For them this is probably the only benefit they gain from what is otherwise a "useless" property.

While it is certain that the quail catching business provides a considerable income to an estimated 500 families in North Sinai, it is more difficult to assess its relative importance for the local economy as a whole. In 1990, quail catching was estimated to have generated about L.E. 500,000. A moderate sum, which cannot be considered of great importance for the local economy. The conclusion

is that quail catching is important to a relatively small number of individuals, but is of limited value for the local economy as a whole.

It is estimated that about 20,400 quails were captured along the 17 km shoreline of the Zaranik Protected Area in 1989, which were worth around L.E. 30,600. In 1990, quails were sold for L.E. 3 - 4 a pair at El-Arish market. Quail catchers practice a variety of other activities, while stationed near their nets, which provide additional funds, which should be regarded as directly related to the quail catching season.

The quail netting activity is most intensive from just before sunrise until 8.00 a.m. After that, the catchers usually go to the nearby sea to catch fish, leaving the nets under the supervision of their children or wives. This is a direct benefit from having quail catching permits, which allows the catchers to enter the coastal area and thus they are able to practice their fishing, otherwise they would be banned from the area by the coastguard. Their fishing activities probably provide the catchers with more income than the quail catching. These men usually fish from the shore using explosives. The catch provided by this method is sometimes massive, ranging between 20 to 100 kg/explosion. It is said that catchers leave their trammel nets standing long after the quail migration season is over (until the end of October), just to take advantage of the good fishing opportunities at that time of the year.

Bedouin families in North Sinai, including many of those involved in quail netting also practice falcon trapping during the autumn bird migration period. Several techniques are employed to capture the falcons, all employing a pigeon as a lure. Bird trappers aim to catch a large falcon, in particular a first year female peregrine *Falco peregrinus* or the saker *Falco cherrug*. A single peregrine was said to be worth L.E. 12,000 – L.E. 16,000 (approximately US$ 4,800-6,500 in 1989 and up to L.E. 25,000 (US$ 10,000) in 1990 (Salama & Grieve 2000). However, capture success is very low. In 1988 only, 15 peregrines were estimated to have been caught in the whole of the North Sinai Governorate. Peregrines are bought by dealers from outside North Sinai and eventually these birds find their way (illicitly) to Saudi Arabia and the Gulf States.

All the catchers encountered by Vatry & Baha El Din (1991) as well as Salama & Grieve (2000) lived in North Sinai. Unlike quail catchers, most falcon catchers are young adult single males, who usually travel every day from urban centers to their catching grounds. They usually practice catching in small groups, covering a certain stretch of land, sharing expenses and responsibilities and splitting any suiting profits.

Falcon catchers are not required to obtain a permit from the military (like that for quail catchers), because their activity is mostly limited to inland areas, where there is little fear of smuggling. Compared with the catching of quail,

falcon catching is far less socially and economically broad-based. It could be viewed as a form of gambling, practiced chiefly by men, who are willing to expend time in return for possible riches. The individuals who participate in this activity are usually seasonal workers or fishermen and they invest more time in this occupation than in catching birds.

All forms of hunting have been prohibited within the Zaranik Protected Area since its formal creation in 1983. Prior to this, it was forbidden to hunt certain kinds of wild animals, such as birds of prey, which was regulated by various Ministerial and Governorate decrees issued in the early 1980s .However, quails and falcons trapping were practiced within the reserve every year until 1990, and are still continuing in the region around the reserve. There is evidence that small scale egg collecting (mostly from little tern nests) occurs at Zaranik and elsewhere in Bardawil, although there is no apparent market for these eggs, generally they are consumed by the collector families (Abdel-Wahab 1999).

In autumn 1990, a concerted effort was made to impose the hunting ban within the Zaranik Protected Area by the North Sinai Office of the EEAA in El Arish. No permits were issued to quail netters and the reserve was patrolled by officers searching for falcon trappers, resulting in much reduced incidence of illegal bird trapping at the reserve (Abdel-Wahab 1999).

It has been revealed that 98% of residents hunt the migrating birds by using their trammel nets; the taraha, the esh, and insectivorous bird traps. They rarely use guns. About 90% consider hunting birds as an important source of their income. 80% of them are willing to give up hunting, in exchange for:

- Executing food aid programs like in middle Sinai,
- Creating alternative labor opportunities and new income sources for the local people (e.g. fish farms, handicrafts, poultry farms, etc.),
- Supply fodder in subsidized prices for animal breeders,
- Building residents equipped with all services for the local inhabitants,
- Improving breeds of goats and sheep to increase their income,
- Building pigeon towers instead of hunting the migrating birds.

Many inhabitants stated that the authorities prohibited hunting without offering any compensation. Now there is an open argument between them and the management team of the Protectorate, the army border control, and the North Sinai Governorate. These agencies are trying to cooperate in the protection of the natural resources in the Protectorate, which requires the integration of local decision-makers or local Bedouin groups.

Nowadays there are certain beneficiaries that are officially allowed to hunt inside the protected area, and they receive the hunt licenses from the Governorate. This is a contradiction and causes misapprehension among the local inhabitants. Many residents complain about this segregating policy which leads to dissatisfaction among the claimed land users.

14.4.5 Salt Factory

El-Nasr Salt Company is situated at the southern border of Zaranik Protected Area and extents towards the south of the Zaranik Lagoon. The factory is owned by El-Nasr Salt cooperation, which is under control of the Ministry of Minerals and Petroleum. The average production of the company is about 193,000 tons of Salt. Approximately 123,000 tons are exported from the port of El-Arish and 70,000 tons for local market.

The company will expand in the future to increase their salt production up to 217,000 tons. Other expansion plans are not implemented for the time being due to possible privatization of the company. The company occupies around 80% of the southern part of the reserve of its property and the expansion will be in the remaining 20% of the property.

The company has 75 permanent workers, 80% of them live in El-Arish, and 20% live in the surrounding villages and Bedouin communities mainly Sebika, Mazar and Abu Zatun communities. The company employs 35 workers, from the surrounding area, on daily basis. There are 40 other workers who live in the barracks next to the company; all from the Nile Valley (Sharkia and Dakahlia Governorates), but they are employed by the transport contractor, who is responsible for moving the salt production out.

The salt factory has positive effects within the Bardawil area and the protected area. It is located as a buffer zone between the Zaranik lagoon and the sand dunes in the south. This makes it more difficult for local people to access the central part of the protected area. The wide open water areas that are used to extract salt from seawater have positive environmental impact because they raise humidity in the air through evaporation.

Furthermore, the salt plant provides new suitable habitats for some species of birds, notably greater flamingos *Phoenicopterus ruber*, avocet *Rescurvirostra avosetta* and black-winged stilt *Himantopus himantopus*, which breed within the salt plains of the protected area. The creation of small artificial islands in the plains of the salt factory encourages breeding of the above-mentioned species in this area. These non-natural habitats seem the least disturbed area of the reserve.

Additionally, the salt factory needs to adjust its methods of production to lower the negative environmental effects. For example, the pumping station of the salt plant, that intakes water from the Zaranik Lagoon into the shallow salt-

water lagoons, does not provide suitable protection for small fishes (young), as they are driven up into the salty lagoon and reduces the amount of fish inside the Zaranik lagoon. A suited net for protection was installed in 2005.

No assessment of the impact of the development and operation of the salt-producing facility on the wildlife within the reserve were carried out. Such study is very important to analyze the environmental impacts of salt factory, thus no further expansions should be undertaken.

14.4.6 Recreation and Tourism

Urban expansion and tourism development has consumed large tracks of habitat along the Egyptian Mediterranean coast. Urban and tourism development is taking place in the North Coast between Alexandria and El Alamein, at a very rapid pace. In the past decade, most of the structures currently found along the coasts of the region have been erected. Tourism seems to be the magic word that made our coasts destined to be developed in the same fashion. Wall to wall tourism developments: whether by plan or not, transformed in recent years, the North Coast into cement blocks of tourist resorts as the "planers" call it.

The North Sinai Mediterranean coast is likewise under heavy pressure from tourism development. Tourism resorts are spreading east and west from El-Arish, up to the borders of the Zaranik Protected Area. There is also intensive development for tourism in northwest Sinai on the coast west of Lake Bardawil. These developments lead to the complete destruction of the sites they are built on. It also leads to the degradation of vast areas surrounding them and wildlife, which is impacted by the various activities, associated with the construction and operation of these developments (such as building material extraction, waste disposal and disturbance).

The Mediterranean coast of Sinai has a good climate during the year and many of palm-fringed beaches still exist. These tourist potentials attract both Egyptian and foreign tourists, especially from the Arab countries. The major beaches along the coast are situated close to El-Arish like El-Nakheel and El-Masaeid sand beaches. Furthermore, there are beaches in Romana, Rafah, Abu Shinar and El-Sheik Zuweiyed.

However, oil pollution, in the form of tar balls and oil-covered flotsam and jetsam, affects the whole coast line from Rafah to Port Said and it is a serious problem for visitors. During the summer months (the peak of the Egyptian holiday season), there are jellyfishes that sting and causes enormous pain, infesting the coastal waters of North Sinai.

Additionally to the wide and long sand beach, there are a number of archaeological sites in the North Sinai. There are two historical sites within the protected area, the buried towns of El-Flusiyat (Ostracine) and El-Koyenat,

dating from the Roman and Islamic period's, respectively. Other historic sites near Zaranik include Ketab El-Kals (Cassius) on the sandbar separating the Bardawil Lagoon from the Mediterranean sea, Tel El-Farma (Pelusium), El-Mohammadiat and Kattiah at the western end of the Lake Bardawil.

The Ministry of Tourism, the North Sinai Governorate and private investors are actively trying to develop different types of tourist accommodations. Mainly for summer visitors, but recently also it is planned for the whole year; tourism hotels, tourist villages, chalets (bungalows), youth hostels and camping sites are in construction.

In the current pattern of development, these tourist facilities are constructed between the narrow space of the seashore and the coastal road. The majority of investments are conducted in and around the city of El-Arish, and they are progressively spreading westwards towards the Zaranik Protected Area. The tourist village "Coral Beach" has been opened in the beginning of 2000. It is constructed right at the eastern border of the reserve.

However, there are only little tourism movements, occasional visitors of ornithologist, hunters and recently school classes from the surrounding area, mainly from El-Arish. This is due, in part, to the lack of faculties and promotion of the site, but mainly due to the restricted access to the shore, sandbar and the Zaranik Lagoon placed by military authorities.

There is a considerable potential for tourism, especially ecotourism in the Zaranik Protected Area. The current economic value of the area is not fully known but the economic activities and the current land use make it clear that it is not too high.

14.4.7 Small Industries

Traditional needlework (handicraft) for personal use and sale to merchants used to be a common activity in rural families. Today, families still actively practice needlework but the young, educated girls are mainly interested in other activities. Only low-income groups within Bedouin tribes still use the needlecraft as a source of income. It can be anticipated that with increasing agricultural practice, reliance on needlecraft will become less important. But this is an area that deserves development.

Moreover, from the main small industries are processing compressed dates, the date palm by-products and animal hair and wool. Most of inhabitants bring their products to Elwesia Thursday market or to Bir El-Abd or they sell it along the Quantara – El-Arish road.

14.5 EXPLOITATION SYSTEMS

14.5.1 Land Use Planning

The aim of land use planning is to create the preconditions to achieve development that is sustainable, environmentally sound, socially desirable and economically appropriate. Such requirements are best met by a decentralized approach. Consequently, the key principle of decentralized land-use planning "gestion de terroirs" is more likely suitable on local context, in a flexible, transparent and participatory approach.

Present day sources of conflicts in land-use planning include traditional rights of local communities and the drive for expanding urban and industrial centers. Many divergences develop out of the need for extension or intensification of the agricultural land use versus the biodiversity and value of non-polluted "natural" landscapes. The Zaranik Protected Area is facing these problems. The poor soil and low rainfall effectively lowered development of agriculture and pasture within the area. The fishing is limited to Zaranik Lagoon.

However, land-use planning not just includes the protection of the natural habitats; it has a further dimension, namely the stakes of all interest groups. Planning involves anticipation of the need for change as well as a reaction to it. Its objectives are set by social or political imperatives and must take into account the existing situation. People's needs drive the planning process.

Three groups of participants are directly involved in the land use planning of the Zaranik Protected Area; the first group is the **land users**. These are the people living in the protected area whose; livelihood depends totally or partly on the land. They include, not only the fishermen, farmers, herders and others, who use the land directly, but also those who depend on these people's production. The involvement of all land users in planning was essential. Ultimately, they had to put the plan into effect and must therefore believe in its potential benefits, as well as in the fairness of the planning process. Without the support of local leaders, the plan is not likely to succeed. Achieving effective public participation in the planning process is one of the main goals.

The second group is the **decision-makers** (e.g. the North-Sinai Governorate and the representatives of the EEAA, who are responsible for putting plans into effect). They play a key role in encouraging public participation through their willingness to expose their decision and the way they are reached to public scrutiny.

14.5.2 Wildlife Utilization

In general, hunting within protected areas is not permitted, but in special cases, like the cormorants, that consume great amounts of the fish resources; this bird population must be controlled. When following the principles of

sustainability (optimal rates of utilization), wildlife can be used as every other renewable resource.

14.6 PROBLEMS AND NEEDS EXPRESSED BY THE INHABITANTS

Shaker *et al.* (2000) revealed that most of the inhabitants and fishermen face several problems, which can be summarized as follows:

1. The problem of closing Boughases (I & II), that affects the depth of lake water and salt concentration, and these have been opened by the MedWetCoast project.
2. Preventing fishermen from staying in their huts during the prohibition period of fish catching.
3. Prohibiting bird hunting in the protected area particularly on their own land and decrease the possibilities to exploit it in tourism.
4. The absence of social infrastructure in fishermen village.
5. Low fish productivity of lake Bardawil which led to the increase of unemployment rate of fishermen, so they suggest creating new job opportunities by establishing factories for processing and canning fish or build up fish farms.
6. Although compulsory insurance is desirable, the retirement pension is low (L.E. 38 - 70) and retirement age is 65 years, so they request increasing the pension and lowering the retirement age down to 60 years.
7. The harmful effects of migrating birds particulary cormorants, *Pholocrocorax carbo sinesis,* which eats fish during the winter season from November to March. One bird eats about half kilogram of fish per day, mainly of the supreme kinds like seabream and small fishes. In another study, the same was mentioned that Lake Bardawil's fish eating birds cause damage to fish stocks and adversely affect the economic returns of fishery. The amount of fish eaten by cormorants daily in Lake Bardawil reached up to two tons in the winters of 1989 until 1990 (Atta 1992).
8. The harmful effect of these birds is during the winter season from November to March. The total number of these birds attains up to 15,000 per day, so the daily loss of fish may be 7 tons. This makes 500 - 600 tons a year, assuming that their occurrence period in the lake is about 75 days. The monetary value of annual loss can be estimated up to L.E. 9 - 10.8 million.
9. Quail netting activity has the highest economic value compared with other birds. The quail netting harvesting period is about 2 –3 hours daily. Every autumn, from early September to late October, many inhabitants stretch their nets continuously along the coast. Most of the trapped quails are then taken to different markets. The most popular quail market is in El-Arish.

The average weight of a bird is about 150 - 200 gram, with a selling price of about L.E. 2 - 4. The total income of quails netting along the season amounted to L.E. 3,000 - 4,000. The average net profit per quail catcher ranged between L.E. 600 - 800. From their point of view, the income generated from quail netting is sufficient to satisfy their daily needs during the prohibition period of fishing.

Falcons' hunting is considered one of the most important economic activities of bird hunters. The average selling price per falcon ranges from L.E. 20 - 30 thousands. The hunted number of falcons does not exceed 10 birds during the hunting season. The famous market of falcons is located in Salmania in Sharkia Governorate, as it is considered, the largest market for the scarce animals and birds. Most of the customers of that market are coming from the Arabian Gulf to buy falcons. Some of them come to the protected area to participate in bird hunting season, particularly falcons.

The bird hunters stated that the prohibition of bird hunting caused a big loss for those who are professional in hunting falcons. In compliance with CITES, Government gave instructions to all ports to prevent falcons from going out the country borders, a matter which caused decrease of their prices.

14.7 IMPACTS OF EXPLOITATION AND RECOMMENDATIONS

The Zaranik Protected Area is currently used or visited by several groups of people. Their activities include fishermen, agriculturists, pastoralists, military guards, hunters and visitors (like Egyptians and foreign ornithologists), and are mostly incompatible with the wildlife conservation. The most significant primary impacts are:

- The loss of natural habitats and increased pressure on remaining wild animals and wetlands. The desert reclamation scheme will lead to the loss of important habitats for flora and fauna.
- Displacement of existing natural population and traditional land use activities.
- Loss of known and unknown historical and archeological sites. Over 1,000 known archeological sites and numerous other sites and objects yet to be surveyed and excavated will be threatened unless a salvation operation is executed.

Participation of local people in conservation efforts is needed. To achieve this goal, the participation must be more than encouraging local people to sell their labor in return for food, cash or materials. Efforts should be exerted to build up local skills, interests and capacity.

The proposed zoning system in the management plan of the Zaranik Protected Area, which promotes nature conservation in selected areas and

human use in others and different buffer zones, should be considered for the whole Lake Bardawil. In the future, the whole Zaranik Protected Area should be treated as Zone A, where the majority of human activities, including fishing, industrial and urban development are controlled. These activities may, in the long run only, be permitted in other areas around the Bardawil Lagoon.

El-Nasr Salt Extracting Company is a welcome bar for an expansion of the urbanization from the east side. If the company has to be sold to private enterprise, conditions should be guaranteed from the new owners, that the current activity (salt extraction) should not be changed. Other expansion plans to set a factory for soap and other chemicals must be carefully examined.

14.8 SUMMARY

The majority of North Sinai's population is mainly of Bedouin origin, although many urban inhabitants are non-Bedouin. Population number is about 305,000 individuals. The Bedouin still practice the traditional lifestyle, which is adapted to the desert environment. Some of them have settled in "rural communities". During the last two decades, there was a migration movement towards the cities in North Sinai, especially young and educated family members who refused to stay within the strong family boundaries and moved to the urban centers (e.g. El-Arish, Bir El-Abd, El-Telul and El-Roda).

Administratively, Bardawil area lies in the two administrative districts; El-Arish and Bir El-Abd. Both districts contrast each other; while El-Arish is the capital of the North Sinai Governorate, an urban center; Bir El-Abd is a rural center. El-Arish is divided administratively into four suburbans, four rural units and 24 Bedouin communities. Bir El-Abd administratively is one municipality with 22 rural units and 90 Bedouin communities.

Social groupings in Sinai are based on tribal affiliations. Members of clans are family up to the 5th generation. Clans make up tribes, which are above the 5th generation. There are 12 identified tribes in the region.

The land use systems and the economic activities in Bardawil Lagoon area are closely linked to the physiographic units. The population is living mainly in the coastal zone. Accordingly, fishery is quite common in this part of the Governorate. Lake Bardawil forms an important marine habitat. Rainfed agriculture is a common and important economic activity. Pasturing causes extensive grazing by camels, sheep and goats. Moreover, there is some irrigated agriculture in the district; the irrigation water is often illegally obtained from the Nile water pipeline (which provides the coastal zone with fresh water as far as El-Arish).

There are two types of agricultural activities in the North Sinai region; the traditional and the modern farming methods. The traditional method is applied in rainfed catchment area, where wheat, corn and barley crops are grown. These

crops depend on good rainfall during the winter months to sustain a high yield. In summer, watermelon is usually grown. Date palms have an historic and cultural significance to the Bedouin tribes. Palm beaches are the symbol of North Sinai, even locations and expansion of some villages are a direct result of clusters of date palms.

Modern agricultural method with small-scale drip irrigated agriculture has developed substantially over the last ten years. Vegetables and fruits including tomatos, cucumbers, melons, watermelons and fig, as well as olive trees are grown. The fresh fruits and vegetables are cultivated in the off-season of the Delta, so these cash crops usually get high returns.

Ownership of camels and size of goat and sheep flocks traditionally assess wealth of individual Bedouin tribe members. Today, the economic reliance on livestock is waning. While they are still important in the economy of tribes, the livestock and grazing practices has been superseded by agricultural activities. As agriculture intensifies, livestock are being kept in corrals or yards in order to stop them destroying the crops. Thus, there is increasing reliance on fodder and feed, which are expensive. The overall costs and inconvenience of keeping livestock represent a major factor in the reduction of herds. The most important problems related to pasturing activities are: shortage of dry fodder, limited areas for pasturing and absence of veterinarian care.

Fishing has gained significance for the Lake Bardawil. Although it is yet considered to be one of the best quality fishing areas in Egypt, its production was accounting to about 3534 tons; 0.7 % of the national fish production in 2005. The local Bedouins have historically been involved in fishing of the lake. However, after liberation and the consequent settlements of large numbers of other tribes, fishing was taken up as a major activity. This has led to the creation of five fishing cooperatives, embracing 3,200 fishermen and there are some 1,094 boats in the area. In Zaranik Lagoon, there are about 30 fishermen with 13 small poorly equipped boats, therefore the MedWetCoast project provided them with motorized well equipped boats.

Quail hunting is a traditional activity of the Bedouins of North Sinai. In the past, quail netters were mainly farmers and fishermen. Today, because of the rapidly changing demography of the region, individuals with a variety of occupations practice quail catching. Bedouins also practice falcon trapping during the autumn bird migration period. Several techniques are employed to capture the falcons, all employing a pigeon as a lure.

All forms of hunting have been prohibited within the Zaranik Protected Area since its formal creation in 1983. Prior to this, it was forbidden to hunt certain kinds of wild animals, such as birds of prey, which was regulated by various Ministerial and Governorate decrees issued in the early 1980s.

The North Sinai Mediterranean coast is likewise under heavy pressure from tourism development. Tourism resorts are spreading east and west from El-Arish, up to the borders of the Zaranik Protected Area. There is also intensive development for tourism in northwest Sinai on the coast west of Lake Bardawil. These developments lead to complete destruction of the sites that are built on. It also leads to the degradation of vast areas surrounding them and wildlife, which are impacted by the various activities, associated with the construction and operation of these developments. Additional to the wide and long sand beach, there is a number of archaeological sites in the North Sinai. There are two historical sites within the protected area, the buried towns of El-Flusiyat (Ostracine) and El-Koyenat, dating from the Roman and Islamic periods, respectively. Other historic sites near Zaranik include Ketab El Kals (Cassius) on the sandbar separating the Bardawil Lagoon from the Mediterranean sea, Tel El-Farma (Pelusium), El-Mohammadiat and Kattiah at the western end of the Lake Bardawil.

On the other hand, traditional needlework (handicraft) for personal use and sale to merchants used to be a common activity in rural families. Today families still actively practice needlework but the young, educated girls are mainly interested in other activities. Moreover, from the main small industries are processing compressed dates, the date palm by-products and animal hair and wool. The most significant impacts of inhabitant's activities are:

- The loss of natural habitats and increased pressure on remaining wild animals and wetlands. The desert reclamation scheme will lead to the loss of important habitats for flora and fauna.
- Displacement of existing natural population and of traditional land use activities.
- Loss of known and unknown historical and archeological sites.

Participation of local people in conservation efforts is needed. Efforts should be exerted to build up local skills, interests and capacity. The proposed zoning system in the management plan of the Zaranik Protected Area, which promotes nature conservation in selected areas and human use in others and different buffer zones, should be considered for the whole Lake Bardawil.

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Chapter 15
Management Plan

The National Working Group, established under the Project Development Fund (PDF) for the MedWetCoast Project, selected Zaranik Wetland to prepare a management plan for many reasons. The first is the high value of the Lake as a breeding area for water birds, both on Egyptian and international scales. Consequently it has been designated as an Important Bird Area (IBA) by BirdLife International as well as being a Ramsar site. For these reasons the Zaranik Protected Area is often classified as a "bird reserve".

Established in 1985, Zaranik is the second oldest protected area in Egypt. As part of Lake Bardawil, the site encompasses a relatively large number of unique aquatic and terrestrial habitat types, which are almost pristine. Moreover, the biodiversity of Bardawil area is relatively high (more than 900 known species) including 5 endemic species and about 16 threatened species. The Lake is the cleanest marine water body in the country, and the vast hypersaline mud flat (known as sabkhat El-Bardawil) occupying the eastern fringes of the Lake is also the largest in the country. These habitat types are home for a wide variety of rare and endemic species of fauna and flora, see previous chapters of this book.

After a detailed description, the site has been evaluated along the environmental, social and economic scales, and a management plan was outlined (Kassas *et al.* 2002).

15.1 EVALUATION

15.1.1 Ecological Criteria

15.1.1.1 Fragility and threats

The Zaranik wetland ecosystem is highly fragile. Evaporation from the shallow water body and the use of water in salt extraction are much greater than rainfall and groundwater supplies to Lake Bardawil. The difference is made up by seawater flowing into the Lake from the Mediterranean through its three inlets (bughazes). Closure of these inlets, whether natural or deliberate, for prolonged periods (especially in the hot summer months when evaporation and salt extraction are at a maximum) can result in drying up the water body of Lake

Bardawil, including the open water sector of the Protectorate. In such event all existing populations of plants and animals will be damaged, and the ecological value of the site will be impaired.

In autumn and winter months, temporary closure of one or more of these inlets (especially the natural one in the Zaranik Protected Area) will prevent the necessary movement of fry and adults of those marine species of fish which have to spend part of their life-cycles in the Mediterranean for spawning. Obviously, productivity of such species will drop sharply and with it income that might have otherwise been gained if those species had continuous free access to the sea through the inlets. Replenishment of the Lake's water with marine species of phytoplankton and zooplankton will also diminish. Filter-feeders which depend on such organisms will starve and the productivity of the entire fish population will dwindle drastically.

15.1.1.2 Rarity

The Zaranik Protected Area is unique among all coastal wetlands of Egypt in being so far almost pristine. Its open water sector is part of Lake Bardawil which is the only truly oligotrophic coastal wetland in the country. Furthermore, it is endowed with a range of habitat types of which the vast expanse of mudflat known as sabkhat El-Bardawil is the largest of its kind in the country.

Zaranik is remarkably rich in endemic, near-endemic, rare and globally-threatened species of plants and animals. Two endemic (*Zygophyllum aegyptium* and *Bellevalia salah-eidii*) and 4 near-endemic (*Allium papillare, Biarum bovei, Iris mariae* and *Muscari bicolor*) species of flowering plants add significantly to the ecological importance of the site. Zaranik also harbours 3 endemic subspecies of birds: the Palm Dove (*Streptopelia senegalensis aegyptiaca*), the Swallow (*Hirundo rusticsa savignii*) and the Egyptian Wagtail (*Motacilla flava pygmaea*).

The list of globally threatened species of animals living in Zaranik includes: 4 species of reptiles (the Egyptian Tortoise *Testudo kleinmanni*, the Loggerhead Turtle *Caretta caretta*, the Green Turtle *Chelonia mydas* and the Leatherback *Dermochelys coriacea*), 4 species of mammals, (the Greater Egyptian Jerboa *Jaculus orientalis*, the Fennec Fox *Vulpes zerda*, the Sand Cat *Felix margarita* and the Wild Cat *Felix sylvestris*), and no less than 8 species and subspecies of birds. A subspecies of zooplankton (*Bosmina coregoni maritima*) is reputed to be unknown in the eastern Mediterranean except in Lake Bardawil and the Suez Canal.

15.1.1.3 Naturalness

The low population density, limited rainfed agricultural practice, and total absence of any fish farms or industrial activity in and around Lake Bardawil have combined to render the Zaranik Protected Area the least disturbed coastal

wetland in Egypt. Apart from the problem of over-grazing and the economic exploitation of a small area of the Protectorate in salt extraction, all natural aspects of the Zaranik have been kept intact for centuries. The only natural Sea-Lake connection, Bughaz El-Zaranik, is found in the Protectorate.

The water of Lake Bardawil is subject to invasion by many species of marine plants and animals from the tropics through the corridor of the Red Sea and the Suez Canal. However, these invaders soon become naturalized in the Lake although they may compete with previously established species and affect them to the point of total disappearance. Although this phenomenon of changing species composition might seem to impart an aspect of instability on the wetland ecosystem of Lake Bardawil, with the passage of time it has become part of its overall naturalness.

Typicality

The Zaranik Protected Area is a good example of an oligotrophic coastal wetland ecosystem with a wide range of habitat types (open water, stabilized and mobile sand dunes, hyper-saline mudflats, inter-dune areas, islands, shoreline, inlet and sandbar). Each of these habitat types has its distinctive communities of plants and animals which seem to have adapted well to the prevailing climatic and edaphic conditions.

Special interest

The site has a number of valuable assets which add to its ecological significance. The relicts of a long history as a transit station on the way between Africa and Asia make the place attractive for archaeologists and historians. Military and civil events which took place in the site shall have to be properly documented pending exhaustive excavation of the wealth of archaeological artifacts (stone and brick constructions and huge amounts of pottery) both within and outside the site. The many thousands of colorful birds, resident and migratory, colonizing the islets and feeding in the shallow parts of the Lake throughout the year provide the site with such rare aesthetic qualities which can hardly be found elsewhere. Watching sunsets on Zaranik's sandbar, islets and inland dunes is a memorable experience.

Size

Zaranik Protected Area covers a small area of 250 km^2. As such, it is not among the larger protectorates of Egypt. However, its ecological importance exceeds its surface area as it harbours a large number of endemic, near-endemic, rare and globally threatened species and subspecies of fauna and flora as well as a combination of rare habitat types. The Lake and the islets within the site offer a safe haven with plentiful food and a resting place for many species of migrating and resident birds. The site is also one of the few habitats left for the globally threatened Egyptian Tortoise (*Testudo kleinmanni*).

Diversity

The concept of completeness is well exemplified in the Zaranik Protected Area. Despite its relatively small area, it is endowed with a wide variety of terrestrial and aquatic habitat types, including the largest mudflat in the country. The protectorate is home for a large number of species of plants and animals.

Lower (non-vascular) plants are represented by algae: other groups (e.g. mushrooms, mosses, liverworts, lichens) have not yet been surveyed. Although higher (vascular) plants include no pteridophytes (ferns and fern allies) and only a single species of gymnosperms, angiosperms are well-represented by 152 species of monocots and dicots of which 3 constitute the rich vegetation of sea-grasses in the open water environment.

With the exception of amphibians, all major taxonomic groups of animals are represented in the fauna of Zaranik. The present number of species and subspecies representing some groups (especially the insects and arachnids) may be regarded as only approximate since they have been only tentatively surveyed and the exact identification of these taxa poses a number of difficulties. The annelids of Zaranik have not yet been surveyed. The mammal community is largely dominated by rodents, while the well-documented avifauna includes 241 species and subspecies of resident and migratory birds.

Stability

Except for the natural phenomenon of invasion by marine species of plants and animals from the tropics through the Red Sea and the Suez Canal, the ecosystem in Lake Bardawil and the Zaranik Protected Area is ecologically stable. Salt extraction from water within the site seems to have little effect on the biota of Zaranik since water is filtered before being pumped into the concentration basins.

Ecological position

The Zaranik Protected Area stands out uniquely among all 24 protectorates in Egypt. Qualifications for this singularity include: (i) it is the only oligotrophic coastal wetland, (ii) it has a distinctive richness of endemic, near-endemic, rare and globally threatened species and subspecies of plants and animals, (iii) it encompasses the largest hyper-saline mudflat in the country, (iv) it is an internationally important resting place for migrating birds, (v) it is one of only two Ramsar sites in the country, and has been designated as an Important Bird Area (IBA) by BirdLife International.

Replaceability

In the event of a serious environmental damage to some of the habitat types in Zaranik Protected Area, especially the sandbar, the natural inlet, the islets and the mudflat, it will be difficult to reconstruct them or to rehabilitate

any of the species of plants and animals depending on them, particularly in the case of endemic and globally threatened species.

15.1.2 Socio-economic Criteria

Whatever happens in Lake Bardawil and its immediate vicinity will of necessity reflect on the social structure and the economic status of Zaranik Protected Area. The livelihood of local inhabitants revolves around the water body of Lake Bardawil and will be drastically affected by environmental changes in the area. The two economic activities with the largest capital investment and profitability are fishing and salt extraction; agriculture, livestock herding and bird catching are of comparatively minor economic importance (Shaker *et al.* 2000) . None of these two main activities will be possible if conditions in the open water environment are significantly altered, and it is highly likely that fishermen and their families will desert the area to other locations with better working opportunities.

Land reclamation projects in Northern Sinai and El-Salam Canal that will supply the required irrigation water, are two of the serious threats to Bardawil and Zaranik. Even if the present claims that the water brought by El-Salam Canal is partially treated, that no agricultural drainage will be discharged directly into the Lake and that the reclaimed land is relatively far from the Lake were true, the fact remains that seepage of both irrigation and drainage waters from the newly cultivated fields through the soil of loose sand will eventually end in the aquifer beneath the Lake and its catchment area. Fresh groundwater supplies will become unsuitable for human consumption. Salinity level in the Lake will be altered and all species adapted to the present level will be affected.

It is intended that the reclaimed areas should attract many newcomers to Northern Sinai in order to relieve the human congestion in the Nile Valley and Delta. The inevitable consequence of this internal immigration is that the social structure of the region will no longer be the same. Domestic wastes of the new settlements in the vicinity of Lake Bardawil will be added to agricultural wastes and pollutants (pesticides and fertilizers) and will undoubtedly alter the environment of the region.

The impact of the international highway crossing the entire width of Egypt from Rafah (on the borders with Palestine) in the east to Sallum (on the borders with Libya) in the west and running directly along the southern boundaries of Zaranik Protected Area is yet to be fully investigated. Increasingly heavier traffic on this dual carriageway to transport people, salt, fish and agricultural produce is having adverse effect on the purity of air in the region. This is particularly noticeable during the summer months when thousands of trucks and other types of vehicle use this highway to transport holiday makers and a wide variety of products (peaches, tomatoes, cantaloupe, salt, fish, etc.) between N. Sinai and mainland Egypt. Greater exchange of

people, cultures, traditions, trade and other socio-economic aspects will ensue as a natural consequence of this ease of movement.

The recent inauguration in 2002 of Mubarak-El-Salam bridge, which crosses the Suez Canal at El-Qantara, has also greatly facilitated the connection between N. Sinai and the rest of Egypt, thus enhancing further the movement of population and freight between them. The railway line intended to run across N. Sinai between El-Arish and El-Qantara is under construction. A single-file track covering about half the length of this line (the distance between El-Qantara and Bir El-Abd) has already been completed but has not yet entered into public service. When this railway line is fully functional, movement of people will become easier and faster. Local culture, especially of Bedouin, will be under serious threat and preservation of folk tradition must be taken into consideration.

Human health in the area is directly correlated with ecological consequences of El-Salam Canal project. Thus, bilharziasis is hitherto unknown in Sinai. However, there can be no guarantee that the partially-treated irrigation water running through El-Salam Canal and its 8 branches will not carry with it the vectors of this disease which has so far plagued generations of Egyptians in the Nile Valley and Delta.

15.1.3 Potential Value

Fish productivity of Lake Bardawil is far less than that of other coastal fisheries. It is estimated that the present fish productivity is only about half of its optimal value, considering that it is one of the best environments for production of quality fish. Therefore, a study seems to be needed in order to determine the optimum sustainable productivity of Lake Bardawil. With an ecologically sound management scheme based on the results of such study the productivity and profitability of the Bardawil fishery would be greatly improved.

A better standard of living for local inhabitants may be achieved with a programme aiming to encourage handicraft and traditional industries such as: (i) the use of date palm leaves in the manufacture of various items of furniture, (ii) the use of goat and camel hair in weaving carpets and rugs with characteristic Bedouin patterns, and (iii) the use of simple cotton materials in tailoring hand-made and magnificently embroidered dresses. Such activities will involve a large proportion of the otherwise unemployed female sector of the local society in useful and income generating work. They will also have the added advantage of preserving some of the local cultural heritage and tradition.

Zaranik Protected Area can contribute greatly to the enhancement of tourism in N. Sinai. The relatively long distance between El-Arish and other major cities in mainland Egypt, and the limited recreation facilities and public services in El-Arish have made the clean soft sandy beaches of N. Sinai the preferred holiday destination of only a few enlightened and well-to-do

Egyptians (mostly from Cairo). With additions and improvements in the bird watching hides, public amenities (e.g. a playground for children) and refreshments in the visitors' center, the Protectorate should attract increasing numbers of seasonal holidaymakers. As a means of achieving this goal, part of the revenue collected at the Protectorate gate should be directed towards publicizing the site and its natural history museum.

The present infrastructure of the site and the experience gained by the its management team in preparing and implementing a conservation management plan place members of that team in an ideal position to act in future as hosts and demonstrators to other protected area managers both from Egypt and elsewhere in the Mediterranean. Zaranik would then become a notable training center of regional repute.

15.2 IDEAL LONG -TERM OBJECTIVES

The present situation of Zaranik Protected Area in which it covers only a small part of Lake Bardawil is rather precarious, vulnerable and could deteriorate in the future. Ill-advised management of the Lake plus the detrimental impact of major development projects (land reclamation for agricultural purposes, El-Salam Canal, new and expanding urban centers, the international highway, the new railway line, the fast proliferation of large-scale seaside resorts, etc.) will undoubtedly impact the current pristine status of the site, possibly beyond repair. All of these projects are in various stages of implementation and it will not be long before their undesirable impact on Zaranik will be felt.

Therefore, in order to keep the changes in the area under control and to minimize their impact on the Protectorate, the ideal concept envisaged for Zaranik is that it should become a core conservation area for the totality of Lake Bardawil and its immediate terrestrial surroundings. In other words, the boundaries of the Protectorate should be expanded to include the entire Bardawil region. The newly added areas (aquatic and terrestrial) will become an associated zone and the enlarged protectorate will be managed on the basis of sustainable development (i.e. environmental management). The knowledge and experience gained from the management of the present limited area of Zaranik will be applied to the rest of the expanded protectorate.

In the light of the foregoing remarks, the following are the main long-term objectives arranged in a descending order of priority:

to maintain and enhance the ecological and biodiversity values of the site,

to conserve available resources through environmental management,

to improve the socio-economic opportunities of the local population,

to develop public awareness and participation in nature conservation,

to resolve existing legal conflicts, especially those of land ownership,

to expand the protectorate to include the totality of Lake Bardawil and its immediate terrestrial surroundings, with Zaranik as its core zone.

Expansion of the boundaries of Zaranik Protected Area will be carried out in accordance with provisions of the Ramsar convention especially paragraph 5 of article 2 ("Any Contracting Party shall have the right...to extend the boundaries of those wetlands already included by it in the List, ..."), and paragraph 2 of article 3 ("Each Contracting Party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as a result of technological developments, pollution or other human interference. Information on such changes shall be passed without delay to the organization or government responsible for the continuing bureau duties specified in Article 8").

15.3 CONSTRAINTS OR MODIFIERS

The management plan of the Zaranik Protected Area should be a legal and technical instrument which helps to achieve the main long-term objectives as well as to maintain the delicate balance between the interests of the local population and the sustainable conservation and development of the site's resources. Apart from some minor changes in the zoning of the enlarged Protectorate, extending the boundaries of Zaranik is not expected to necessitate major changes in the management plan. Implementation of the projects set out in the management plan is likely to meet with some difficulties and constraints. Some of these constraints already exist, while others are expected to emerge with time. The plan of action should therefore be designed in such a flexible way that it would cater for these existing and expected constraints.

15.3.1 Potential Constraints Within the Site

15.3.1.1 Natural constraints

They include:

the limited amount of rainfall affects growth and regeneration of the already scanty vegetation and consequently hampers efforts to overcome the problem of over-grazing,

shoreline erosion in some parts and accretion in others by wind and marine action can have a profound effect on the geomorphology of the Protectorate,

the only natural inlet (Boughaze El-Zaranik) in the Protectorate is always prone to silting up or blockage with boulders moved by strong wind and waves,

the possibility of a permanent rise in seawater level (consequent of global warmth) can overwhelm portions of the sandbar separating the Lake from the

Mediterranean Sea causing major uncontrollable changes in the entire aspect of Lake Bardawil.

15.3.1.2 Legal constraints

Other constraints are purely legal and currently apply equally inside and outside the boundaries of Zaranik Protected Area. Therefore, they will also have to be resolved if and when the present boundaries of the site are extended to cover the whole of Bardawil. They include:

the problem of undocumented claims to land ownership and land tenure by some local inhabitants,

conflicting laws relevant to various aspects of the environment,

conflicting interests and responsibilities of the multitude of governmental institutions with roles to play in the management of Lake Bardawil and the Zaranik Protected Area.

15.3.2 Potential Constraints Outside the Site

In addition to the above-mentioned legal constraints, the implementation of the major development projects in N. Sinai poses a number of problems in the management of the Protectorate before and after the extension of its boundaries:

drainage water from the newly reclaimed and irrigated lands will change water quality in the aquifer beneath the Lake and its catchment area; a change in the water quality and the biota of the Lake will eventually ensue,

agricultural pollutants and waste products from the newly reclaimed lands which may find their way into the Lake will have adverse impacts on its fauna and flora,

domestic drainage and waste disposal from the new and expanded rural communities and urban centers,

waste disposal from the proliferation of large-scale seaside resorts bordering directly on the eastern and western fringes of the Lake,

the problem of land speculation as a result of development further exacerbates the legal issues of undocumented claims of local inhabitants to ownership of large parts of the Protectorate,

the serious danger of loosing the local knowledge and cultural heritage of the population,

health hazards hitherto unknown in Sinai and caused by the partially-treated water brought into N. Sinai through El-Salam Canal,

invasion by fresh and brackish water organisms carried with the water brought into N. Sinai through El-Salam Canal,

air pollution caused by increasingly heavier traffic on the international highway running directly along the southern boundaries of the site.

15.4 BROAD OBJECTIVES OF CONSERVATION

15.4.1 Maintaining and Enhancing the Ecological and Aesthetic Values of the Site

Success in the process of enlarging the territory of the Zaranik Protected Area will provide it with the much-needed 'shield' against the combination of ecological and biological threats of the on-going development projects. The intended strict conservation (core) zone at Zaranik will remain as pristine as it has always been, and will continue to be the safe haven for resident and migratory species of birds, the rare habitat of all endemic and globally threatened species of plants and animals.

15.4.2 Conserving the Site Resources through Environmental Management

The benefits of environmental management in N. Sinai cannot be over-emphasized. Fish production from Lake Bardawil, for instance, is currently at about half of its possible potential but will attain its optimal value with a sound management scheme which sets an overall fishing policy for the Lake. Similar situations of reduced productivity or over-exploitation of resources will be rectified only through a policy of wise use which takes into consideration the carrying capacity of the site and the needs of the local population, thus avoiding the possibility of resource depletion.

15.4.3 Improving the Socio-economic Opportunities of the Local population

The anticipated increase in the local population as a result of the development projects which will facilitate and speed up the movement of people between N. Sinai and mainland Egypt and attract many newcomers from the Nile Valley and Delta, will necessitate the creation of new income generating opportunities. Alternative sources of income are also needed for local fishermen and their families during the annual period of 4 months (January – April) when fishing is not allowed in Lake Bardawil. These alternative sources are all the more necessary in view of the fact that the present levels of income are so low that the local inhabitants in general are not in the habit of setting aside part of their income as savings to be spent in periods of no income.

15.4.4 Developing Public Awareness and Participation in Nature Conservation

The role of local population in facilitating the management of the Protectorate and in achieving long-, medium- and short-term objectives cannot be ignored. However, in order to involve members of the local society in efforts of nature conservation, they have to be convinced of the value of available

natural and cultural resources and of keeping these resources in a usable condition for successive generations. Hence the significance of programmes aiming at raising the level of public awareness in the region. Furthermore, local inhabitants are a significant component of the stakeholders in the Protectorate and their active participation in the processes of management and decision-making is necessary for the successful implementation of any conservation programmes.

15.4.5 Resolution of Conflicting Legislation

Disentanglement of the web of existing legislations of the environment will define exactly the roles, responsibilities and legal rights of all parties concerned with the management of the protected area before and after the expansion of its territory. Over-riding management decision-making will have to be placed with only one institution (the management council), while consultation, co-ordination and co-operation with other institutions will be closely observed. The long-standing problem of undocumented claims to land ownership and tenure by local inhabitants should be resolved satisfactorily. Achievement of this objective should alleviate the present conflicts between claimers of land (aspiring to acquire sudden wealth through land speculation) and members of the management team who have to prevent them from introducing any major changes in the nature of the site.

15.4.6 Expanding the protectorate to include the totality of Lake Bardawil and its immediate terrestrial surroundings, with Zaranik as its core zone

This objective is of special importance if the currently pristine status of the Zaranik Protected Area is to be kept intact and protected from the harmful impacts of the development projects being implemented in the Governorate of Northern Sinai. The present boundaries of the Protectorate will be those of a strict conservation (core) zone while the rest of the enlarged protectorate will be treated as an associated zone with an environmental management scheme which strikes a balance between the necessities of sustainable use and development of the resources and the obligations of species and habitat conservation.

15.5 OPERATIONAL OBJECTIVES

Since none of the above-mentioned constraints is insurmountable, the set of ideal (long-term) objectives will determine to a large degree the sets of operational (practically achievable) objectives. Each operational objective will then require a number of implementable projects; the outcome of all such projects should ultimately serve the goals of management of the site.

15.5.1 Maintain and Enhance the Ecological and Aesthetic Values of the Site

Propose a scheme of zonation and prescription,
Establish referral collections,
Establish a wild. life clinic,

Initiate ex. situ conservation measures,
Establish a system of data management,
Establish an environment monitoring system,
Initiate a programme of research.

15.5.2 Conserve the Site Resources through Environmental Management

Improve the situation of law enforcement,
Develop and maintain conditions for improvement of fish productivity.

15.5.3 Improve Socio-economic Opportunities for Local Population

Initiate capacity-building schemes,
Develop ecotourism,
Develop alternative income-generating schemes,
Fund raising.

15.5.4 Develop Public Awareness and Participation in Nature Conservation

Raise level of public awareness,
Initiate publicity programmes,
Involve local population in management.

15.5.5 Resolve Conflicting Legislation

Revise legislative and institutional aspects.

15.5.6 Expand the Protectorate to Include the Totality of Lake Bardawil and it Immediate Surroundings with Zaranik as its Core Zone

Survey Lake Bardawil and its immediate surroundings.
Take legal steps to declare Lake Bardawil and its immediate surroundings a protected area.

15.6 IMPLEMENTATION

15.6.1 Management Strategies

In an almost pristine site as the Zaranik Protected Area, the management strategy should be based on non-intervention in the habitat types and maintenance of species diversity of the site.

For public use (recreation, visitor facilities, education, demonstration): the most suitable management strategy seems to be that of partially open (or zoned) access. Areas with endemic, near-endemic and/or globally threatened species will not be open for public use. Other areas around the Visitors' Centers, selected spots with bird watching hides, the location near the archaeological stone constructions will be demarcated, the ways to them will be clearly sign-posted and made accessible for public enjoyment. Entrance fees will be collected.

For post-graduate studies and research: the present strategy of controlled facilities should continue to be followed. Laboratory, library, accommodation

and logistic facilities of the Protectorate will be available to post-graduate students and researchers on request. Prior reservation arrangements with the Manager will be made. No entrance fees will be collected.

For publicity: a strategy of active publicity is needed. Local and national media should be fully utilized for informing the public of the location, facilities, attractions, importance, purposes, functions and benefits of the site. Printed matter in the form of colourful maps and hand-outs promoting aspects of special interest in the site should be made freely available to the public inside and outside the protectorate.

For estate management: the right of way on the only tarmac road and the unpaved tracks within the site are legally guaranteed only to vehicles and personnel of the Coast Guards, the Police Force and El-Nasr Salines Company. No other permanent constructions are legally allowed on the site other than those of the Coast Guards and El-Nasr Salines Company. Areas with endemic, near-endemic and/or globally threatened species must be fenced.

For miscellaneous issues: the rules and regulations controlling the recruitment and employment of staff, contracting of services, remuneration and other financial aspects including the purchase and maintenance of equipment and buildings as well as the health and safety of employers and employees are set out and implemented by EEAA. Visitors can wander through the accessible areas of the site at their own discretion; provided that visitors do not trespass outside these freely accessible areas, health and safety risks in Zaranik are minimal.

More significantly, perhaps, is the management strategy which should be adopted to influence events taking place outside the site and having profound impacts on it. As a step towards ensuring institutional and public involvement in the management of Zaranik Protected Area the following management setup of two Committees is proposed. This setup has the advantage of replacing the multitude of decision-making institutions which have conflicting interests and responsibilities affecting directly or indirectly the management of the site with a single decision-making (steering) council and a single executive committee.

15.6.1.1 The management (steering) council

The existing council, headed by the Secretary-General of the Governorate of Northern Sinai should be re-structured to consist of:

The Governor of Northern Sinai (Chairman),

The Secretary-General of Northern Sinai Governorate (Vice-Chairman),

The Director o the Protectorates of EEAA.

The Director of Lake Bardawil (representing the Ministry of Agriculture),

The Director of El-Salam Canal Project,

The Manager of the Protectorate (Secretary),

and the local representative of each of the following institutions:

The Ministry of Health,

The Ministry of Housing and New Communities,

The Director of El-Nasr Salines Company at Sebeka,

The Coast Guards (representing the Ministry of Defense),

The Police Force (representing the Ministry of Interior),

Members of Parliament from El-Arish and Bir El-Abd,

The Chief of Fishermen Co-operatives, and

The Chief of a major tribe from El-Arish and Bir El-Abd.

This preliminary structure may be reviewed every two years. The council will be appointed by a decree issued by the Governor of Northern Sinai. The role of this council should be re-formulated to ensure its effective function of decision-making. Meetings of this council should deal principally with the following tasks:

setting policies for the management of the site within the framework of the management plan,

supervising the implementation of projects indicated in the management plan,

reviewing periodically the progress made by the management team in the implementation of projects,

proposing changes in the work plan as the need arises.

15.6.1.2 The executive committee

This is a smaller committee headed by the Manager of the Protectorate and includes all appointed rangers. The functions of this committee are primarily to:

implement the directives of the Management council

oversee the day-to-day tasks of patrolling, and monitoring,

report to the Management council on all new developments in and around the site.

These duties are additional to the official obligations and duties of the Manager and his staff.

15.6.2 Zoning and Prescriptions

There can be two separate zoning and prescription schemes for Zaranik Protected Area: one for the present limited area of 250 km^2 which includes only

a small part of Lake Bardawil, and the other for the protected area after the expansion of its boundaries to encompass the entire area of the Lake.

15.6.2.1 Core zones

The present Protected Area includes several closely located terrestrial ecotopes of extreme ecological sensitivity as they are inhabited by most of the endemic, near endemic, rare and globally threatened species. These require equally extreme care and the highest degree of conservation measures. All of these 'hot spots' are outside any area needed for economic exploitation (e.g. salt extraction, hunting, bird catching, etc.). Hence, total prevention of human activities (e.g. grazing, wood cutting, etc.) in these sites will not have negative impact on the socio-economic situation in the area. El- Fluseyat island, with heaps of old pottery, is of equal cultural and historical importance. It is also a convenient resting place for a number of resident and migratory species of birds. The aims of designating these areas as core zones are:

to protect endemic, near-endemic, rare and globally threatened species of fauna and flora,

to eliminate or minimize the impact of human activities on well-established, rare or unique habitat types,

to preserve the cultural heritage and the aesthetic aspects of the site for posterity.

Four core zones are proposed:

Core zone 1: El-Fluseyat island

Location: **33° 25' 46.42" E & 31° 06' 57.18" N**
Elevation: 0-14 m
Area: 5.3 ha
Priority: High
Main habitat types: stabilized sand dunes, sand flats, salt marsh, aquatic areas.

Justifications:

High species richness: 99 species of flowering plants of which 10 are found only on this island, and many bird species

Endemic and threatened species: including the near-endemic plant *Iris mariae*, 3 endangered mammal species (*Vulpes zerda, Felis silvestris, Felis margarita*), the rodent *Jaculus orientalis*, and the threatened reptiles *Varanus griseus* and *Chameleo chameleon*.

Rarity: most of the rare plant, bird, insect and reptile species are localized on this island

Ease of management: The island is naturally isolated from the mainland of the protectorate and prevention of human activity is facilitated.

Scientific and educational value: The fat sand rat which digs tunnels under succulent shrubs, is a unique animal model for studying obesity and diabetes.

History and cultural heritage: Abundance of heaps of old pottery may offer a key to the history of N. Sinai and its past cultures.

Management strategies:

limited intervention for conservation of habitat types,

maintain species composition,

area must be strictly closed against public use.

Timing: Immediate implementation of projects.

Core zone 2: A bird sanctuary

Location: 33° 27' 56.00" E & 31° 07' 43.13" N **Elevation: 0 – about 2 m** **Area: 0.4 ha** **Priority: high** **Main habitat types: sand flat, mudflat, salt marsh, small islets**

Justifications:

Species richness: 51 species of birds have been identified in the diagnostic survey of autumn 2000.

Ecological significance: the site is strategically important as a stop-over site for about 500,000 migratory birds each autumn.

Globally threatened species: no less than 8 globally threatened species of birds have been listed in this site.

Locally rare species: 10 bird species occur in Zaranik as accidental migrants including the locally rare avocet (*Recurvirostra avocetta*) which breeds in this site.

Vegetation: the salt marsh vegetation includes the vulnerable halophytic succulent *Zygophyllum propinquum*.

Management strategies:

Complete restriction against human disturbance,

Limited seasonal (summer) intervention to conserve habitat types.

Timing: Immediate implementation of appropriate projects.

Core zone 3: The Egyptian tortoise site

Location: 33° 25' 00.44" E & 31° 05' 06.76" N
Elevation: 0 – about 2 m
Area: 0.5 ha
Priority: high
Main habitat types: partially stabilized sand dunes

Justifications:

Vegetation: one of the richest spots with vegetation.

Endangered species: the only site in Zaranik where the rare and globally endangered Egyptian tortoise (*Testudo kleinmanni*) has been found; the two threatened reptiles *Varanus griseus* and *Chameleo chameleon* are recorded in this site.

Endemic species: the rare and endemic halophyte *Zygophyllum aegyptium.*

Habitat rarity: the partially stabilized sand dunes and the interdune areas with low salinity is the only suitable habitat for the Egyptian tortoise are rare.

Management strategies:

Complete restriction against human disturbance,

Active intervention to prevent sand drift by wind,

Increase number of Egyptian tortoise.

Timing: Immediate implementation of appropriate projects.

Core zone 4: The marine turtles site

Location: 33° 32' 59.08" E & 31° 06' 30.01" N
Elevation: 0.2 – 0.9 m
Area: 0.2 ha
Priority: high
Main habitat type: coastal sand flats

Justification:

Rarity: this is the single most important site for nesting of the two marine turtle species (the green turtle *Chelonia mydas* and the loggerhead turtle *Caretta caretta*) on the entire Mediterranean coast of Egypt. Similar sites outside the Protectorate have much fewer individuals and are subjected to threats (mainly collection of eggs and hatchlings).

Management strategies:

Complete restriction against human disturbance,

Maintain species diversity,

Non-intervention in habitat type.

Timing: As soon as funds are available to fence the site.

15.6.2.2 Expanded core zone

When the existing boundaries of the Zaranik Protected Area are expanded to encompass the totality of Lake Bardawil and its immediate terrestrial surroundings, the area enclosed within the present boundaries will be treated as a core zone, except 16.5 km2 currently occupied by El-Nasr Salines Company together with the road and tracks leading to it.

Location: open water, salt marsh (sabkha) and sand bar with natural and artificial inlets
Elevation: 0 – 14.5 m
Area: 250 km^2, except 16.5 km^2 occupied by El-Nasr Saline's Co.
Priority: High
Main habitat types: open water

Justifications:

The same justifications which led to the declaration of the Zaranik Protected Area. They may be summed up in the following:

Species richness: It is disproportionately rich in the number of species of fauna and flora relative to its small area

Habitat rarity: It encompasses the largest mudflat (sabkha) in the country; it is also the only oligotrophic coastal wetland in Egypt with an almost pristine ecosystem

Species rarity: Home for many rare species of aquatic and terrestrial plants, reptiles, insects and mammals

Endemism: A number of endemic and near-endemic species of plants and animals are found in this limited area

Threatened biota: Many species of plants and animals are listed as vulnerable, threatened or endangered; no less than 8 subspecies of birds in the site are globally threatened

International importance: the Protectorate is one of two Ramsar sites in the country and was also designated as Important Bird Area (IBA) by BirdLife International.

15.6.2.3 Buffer zones

With the exclusion of the proposed 4 core zones and the area (16.5 k m^2) currently occupied by El-Nasr Salines Company for salt extraction, the rest of the present area of Zaranik protectorate will be treated as a temporary buffer zone.

The area which will be added to the present territory of the Protectorate (Lake Bardawil) will serve as a buffer zone to the expanded core zone. A separate Management Plan for the additional area will be needed and can be prepared only when detailed studies of site diagnosis, including environmental impact assessment of the major development projects in the region, have been undertaken. However, considering the present ecological and socio-economic situation of the region, the most likely management scheme for the expanded Protectorate seems to be that of environmental management which strikes a balance between the necessities of sustainable use and development of the resources on one hand, and the requirements of species and habitat conservation on the other. Hence the inclusion of some projects in the present management plan for the future development and conservation purposes of the expanded site, especially those concerning fishing which is the economic activity with the largest capital investment and profitability.

15.6.3 Projects

Projects are component elements of the plan of action and the practical tools of achieving operational objectives. An operational objective may be realized by the implementation of one or a group of projects for which a set of requirements have to be secured. Such requirements include trained personnel, equipment and funding. Projects may be implemented in a sequential or simultaneous manner according to the duration and the degree of priority of each project. The following is an outline of the set of projects proposed for the implementation of the six operational objectives.

Operational objective 1: maintain and enhance the ecological and aesthetic values of the site

Project 1: Implement a scheme of zonation

Priority: High

Method: Core zones proposed should be fenced against human interference. Unpaved tracks should be prepared in all buffer zones to allow easy access to places of public interest and enjoyment. Clear signposts carrying place names and coloured arrows should be fixed at all cross-roads inside the protectorate. Continuous maintenance of all signposts for correction and replacement of old ones is a practical necessity. Boundaries of buffer zones may need to be modified to suite new developments in the site; tracks and signposts will have to be modified accordingly.
Cost: $ 100,000 for initial year; 20,000 per annum for subsequent years.

Project 2: **Establish referral collections**

Priority: Medium

Method: Referral collections should be the nucleus of a local natural history museum in the Protectorate and one of its main attractions. Establish the following, to be accommodated in the Visitors' Centre:

herbarium with dried, curated and authentically identified specimens of plants; duplicates should be put on public display,

specimens of birds with informative labels should be put on public display,

specimens of fish, reptile and mammal species in jars with liquid preservative should be displayed,

an entomological collection of local species should be put on public display,

a collection of soil samples to cover all soil types in the site; a specific system of classification of soil types should be adopted and indicated on the labels of samples,

a seed bank.
Cost: $ 500,000

Project 3: Establish a wild life clinic

Priority: Medium

Method: It is a complementary ex situ measure of species conservation. Veterinary care is needed for many birds, reptiles, fish and mammals which are either injured or may arrive to Zaranik in a state of fatigue and exhaustion. This may be annexed to the visitor's center.
Cost: $ 50,000

Project 4: **Take ex situ measures of species conservation**

Priority: Medium

Method: Supply suitable amounts of viable seeds of flowering plants in the Protectorate to the botanical germplasm bank in Sheikh Zuwayed town, 27 km to the east of El-Arish city.
Cost: $ 15,000

Project 5: **Establish a system of data management**

Priority: High

Method: Establish a storage-retrieval system of all available information of the site. The system should be as flexible and expandable as possible. Data in this system should be readily available for exchange with other national, regional and international protectorates. The database of Zaranik should be designed to be compatible with those of a network of similar databases of other protectorates in the country. Design a home page on the Internet for the Zaranik Protected Area.

Cost: $ 50,000

Project 6: **Establish an environment monitoring system**

Priority: High

Method:

Establish a network of stations for collecting samples of water and bottom sediment from Lake Bardawil for physico-chemical analysis. Feed results into the data base. Report changes, especially those that might affect biodiversity. Take appropriate measures to combat or minimize their impact.

Record numbers of birds of every species on a daily basis. Record other items of information such as resident/migratory, season of visitors and passers, breeders, feeding habits, etc. Feed results into the database. Report increases or decreases in numbers and investigate possible causes. Take appropriate measures to redress any unbalanced conditions.

Follow similar steps with other groups of fauna and plankton, the purpose is to fill gaps noted in the previous surveys and to keep records of changes in the biota.

Cost: $ 200,000 per annum

Project 7: Initiate a programme of research

Priority: High

Method and purposes: This programme will be the backbone of all future work in the management of the Zaranik Protected Area (before and after its expansion to cover the whole region of Lake Bardawil and its immediate terrestrial surroundings). It should run initially for three years. The importance of this programme in several fields cannot be over-emphasized, the aims include:

Fill present gaps in our knowledge of some taxonomic groups of plants and animals (e.g. soil microflora, nematodes, mollusks) as well as others which have been studied only tentatively in the site (e.g. insects, arachnids) will have to be bridged through intensive studies. Updated inventories of such groups will be critical for their conservation. Behaviour of certain groups and species of animals (e.g. reptiles, fish) should be studied carefully in order to design appropriate schemes for their conservation.

Assess the carrying capacity of the various ecosystems for grazing and cutting of shrubs by local inhabitants. Results of these studies provide the bases for designing a scientifically sound programme aiming at the control of over-grazing and wood cutting.

Carry out studies on the environmental impact assessment of the major development projects in the region (especially El-Salam Canal, the new

highway, the new railway line, the new urban centers, the rural communities in the newly reclaimed lands). Now that all of these projects have been partially implemented, studies of their environmental impacts will be based on more realistic data. Results of such studies will be immensely valuable in formulating appropriate plans of action aiming at the minimization of adverse environmental impacts, especially for the expanded concept of the Protectorate.

Studies to select the most effective method(s) for improving fish productivity of Lake Bardawil.
Cost: $ 500,000 per annum.

Operational objective 2: conserve available resources through environmental management

Project 1: Improve the situation of law enforcement

Priority: high

Method: At present only the Site Manager, the rangers and the Director of Lake Bardawil have the legal right to arrest violators of the laws concerning protected areas and fisheries. They can only take them to the nearest police station either in El-Arish (35 km east of Zaranik) or in Bir El-Abd (45 km west of Zaranik). This is inefficient and must be corrected by the establishment of one police station inside the present boundaries of the protectorate. When these boundaries are expanded to include all of Lake Bardawil, two additional stations should be established at El-Roda village (10 km west of Zaranik) and at El-Telool village (20 km west of Zaranik). The latter station will be close to the office of the Director of Lake Bardawil and will be of immense help to him in combating illegal fishing activities. Each station should be provided with its own fast boat and the trained personnel to use it.
Cost: $ 70,000 per station (salaries of personnel and running costs are excluded and shall be incurred by the Ministry of Interior).

Project 2: Develop and maintain conditions for improvement of fish production

Priority: Medium

Method: The present fish productivity of Lake Bardawil is approximately half of what it should be considering that it is one of the least polluted water bodies in the country. In order to increase fish productivity, fishermen should be allowed to use fish cages in the Lake with artificial spawning and natural feeding of fish. Emphasis should be laid on the two highly prized and most profitable species denis (*Sparus aurata*) and karous (*Dicentrarchus labrax*).
Cost: $ 100,000

Operational objective 3: to improve socio-economic opportunities for local population

Project 1: Initiate capacity building schemes

Priority: Medium

Method: Organize general training courses for rangers and community guards. Specialized training courses geared towards the qualification of technicians taking part in monitoring schemes and assisting in research programmes in the Protectorate should be undertaken. These courses may be accommodated in the Visitors' Center or the trainees may join appropriate courses in universities and training centers in the country and abroad.
Cost: $ 100,000 per annum.

Project 2: Develop ecotourism

Priority: Medium

Method: Internal tourism to N. Sinai is mainly seasonal and associated with school and university summer vacations from early June to mid-September. This is the period which could be exploited to develop and enhance ecotourism in the site. This project is also related to public awareness programmes. It consists of the following three non-profit sub-projects:

Sub-project 2.1: Establish public amenities in the site. These include a cafeteria, toilets, and vehicles for internal public transport of guided tours to spots of cultural and aesthetic enjoyment in the buffer zones.. **Cost:** $ 150,000.

Sub-project 2.2: Establish playground for children in the vicinity of the Visitors' Center. **Cost:** $ 30,000.

Sub-project 2.3: Establish 5 bird watching hides equipped with suitable telescopes in selected spots in the buffer zones. Positioning of these moveable hides may be changed seasonally.. **Cost:** $ 20,000

Total cost: $ 200,000

Project 3: Develop alternative income-generating schemes

Priority: Medium

Method: This project requires co-operation with the local branch of the "Social Fund" in El-Arish. This is an institution which offers soft loans to start small profit-making industrial and commercial projects. To date, male young graduates have constituted the main bulk of customers of this fund. More emphasis needs to be directed towards encouraging the female sector of society, including Bedouin women, to initiate their own income-generating projects in such fields as poultry keeping and making the characteristically embroidered dresses and other items of clothing. Traditional 'cottage industries' such as

using date palm leaves in the manufacture of baskets and various items of furniture (chairs and tables) should be encouraged. A successful ecotourism campaign should create a number of job opportunities for students during their summer vacations. The Protectorate can assist in this field through organizing frequent sales exhibitions and a marketing programme inside and outside N. Sinai.
Cost: $ 50,000 per annum.

Project 4: Fund raising

Priority: High

Method: Active pursuit of financial resources should be undertaken by the Manager of the Protectorate through the agency of EEAA. Sources of funds which may be approached to secure sufficient money supplies for the implementation of projects outlined in the management plan include national and international institutions. The Ministry of State for the Environment should allocate a fixed annual sum for the Protectorate. Entrance fees and a certain percentage of all licensing fees should be directed to a special fund for the management of the protectorate. Legal steps should be taken to levy additional surcharges on local ecotourism (e.g. a certain percentage may be added to costs of accommodation in hotels and other seaside resorts). Negotiations should be undertaken with the national non-governmental business community for donations and with international donor organizations. Professional experts might be consulted about the most effective methods of fund raising.
Cost: $ 20,000.

Operational objective 4: to develop public awareness and participation in nature conservation

Project 1: Raise level of public awareness

Priority: Medium

Method: This project is essential for the success of all other projects. It should acquire additional significance when it involves executives of the local authority. Either the Visitors' Center or halls in municipal units may be the venue of public lectures and seminars stressing the value and benefits of the Protectorate for the present and future generations. Invitations to these lectures and seminars should be extended to groups of school and university students, fishermen associations, Bedouin tribes, women from local villages, school teachers and clergymen who can in turn pass the message to larger groups of students and worshipers, etc.
Cost: $ 10,000.

Project 2: Initiate publicity programmes

Priority: Medium

Method: Local and national media should be used to publicize the Protectorate. Radio and TV programmes should be used to inform the public of the location, recreational facilities, aesthetic and cultural assets, scientific and educational values of the site. Newspaper articles and advertisements (paid and voluntary) promoting the site and its socio-economic benefits should be published. Printed brochures with attractive coloured maps and photos depicting the scenery of the site may be widely distributed in local educational institutions. The home page of the site on the Internet should be fully informative and periodically updated as it will attract international attention to the site and might be used to assist in the process of securing international donations.
Cost: $ 30, 000 per annum

Project 3: **Involve local population in management**

Priority: Medium

Method: The proposed establishment of a broadly based management council for the protectorate should ensure active participation of representatives of the local population in the processes of decision-making and implementation of the projects outlined in the management plan. These representatives will have the responsibility of informing and convincing the local population of the value of decisions or actions taken by the council and by the management team.
Cost: $ 2,000 per annum.

Operational objective 5: resolve conflicting legislation

Project 1: **Revise legislative and institutional instruments**.

Priority: High

Method: Competent legal experts should be contracted to review existing environmental legislations (laws, decrees, executive decisions and regulations, etc.) and propose solutions to contradictions causing management difficulties and problems. Legal rights and responsibilities of various governmental institutions should also be satisfactorily resolved by placing the mandate to manage the Protectorate with only one institution (the council).
Cost: $ 20,000.

Operational objective 6: expand the protectorate to include the totality of Lake Bardawil and its immediate surroundings

Project 1: **Survey Lake Bardawil and its immediate surroundings**

This should include a biodiversity inventory (biota and habitat types). Ecological and biological ranges of species (especially breeding animals) will indicate limits of the area (Lake and surroundings) to be included in the protectorate. Ecological studies will indicate the sites for ecological monitoring.

Socio-economic studies will indicate bases for management of natural resources.
Cost: $ 200,000

Project 2: Take legal steps to declare Lake Bardawil and its immediate terrestrial surroundings a protected area

Priority: Second to the projects in the Zaranik Protected Area.

Method: Application by the Minister of State for the Environment to the Prime Minister to issue the necessary decree concerning the expansion of the present boundaries of the Zaranik Protected Area to include the entire area of Lake Bardawil and its immediate terrestrial surroundings. The decree must be accompanied with a map showing the new boundaries of the protectorate and its map co-ordinates. Copies of the decree and the map must be distributed widely to all institutions with a role in the management of the Lake.
Cost: $ 5000

Operational objectives	Projects (code and title)	Cost (in $ 1000)
1. Maintain and enhance ecological and aesthetic values	1 Implement a scheme of zonation	140
	2 Establish referral collections	500
	3 Establish a wild life clinic	50
	4 Take ex situ measures of species conservation	15
	5 Establish a system of data management	50
	6 Establish an environment monitoring system	600
	7 Initiate a programme of research	1,500
2. Conserve the site resources through environmental management	1 Improve the situation of law enforcement	70
	2 Develop and maintain conditions for improvement of fish production	100
3. Improve socio-economic opportunities for local population	1 Initiate capacity-building schemes	200
	2 Develop ecotourism	200
	3Develop alternative income-generating schemes	50
	4 Fund raising	20
4. Develop public awareness and participation in nature conservation	1 Raise level of public awareness	10
	2 Initiate publicity programmes	30
	3 Involve local population in management	6
5. Resolve conflicting legislation	1 Revise legislative and institutional aspects	20
6. Expand the protectorate to include Lake Bardawil	1. Survey of Lake Bardawil	200
	2. Take legal steps to declare Lake Bardawil part of the protected area.	5
Estimated costs:	**Total (3years)**	**US$ 3,866,000**

15.6.4 Work Plan

The following work plan is designed on an annual basis in tabular form for the next 3 years. It may be reviewed and updated for the subsequent years as the results of this initial period might deem necessary. The total estimated cost

of all projects is $ 3,081,000. The breakdown of the work plan of each of the three initial years into monthly working schemes should be undertaken by the management (steering) council.

15.7 REVIEW

It is imperative to review periodically the progress made by the management team towards achieving the goals and targets set out in the management plan. The outcome of each review should be an assessment of these achievements, of the constraints and modifiers which hindered implementation of some of the projects allocated for a certain stage of the proceedings, determine possible ways and means of alleviating those constraints and modifiers, and re-schedule the plan of action for the next phase.

15.7.1 The Annual Review

At the end of each year, the site Manager, in collaboration with the executive committee, will have to submit a detailed annual report to the management (steering) council which should cover the following points:

the tasks allocated to the year covered by the report,

how much of these tasks (projects or parts thereof) has been accomplished,

how much of these tasks (projects or parts thereof) has not been accomplished,

temporary and permanent constraints and difficulties (legal, natural, material, financial, personal, etc.) which caused failure to accomplish these unaccomplished tasks,

suggestions and ideas about how to overcome these difficulties in the next phase,

evaluation of the performance of each member of the management team,

a detailed financial statement including all forms of expenditure and revenue.

The management council shall convene to discuss the annual report submitted by the site Manager, evaluate the achievements, approve of the most appropriate procedure to overcome constraints and difficulties, review all financial aspects, and issue new directives to the site manager including the re-scheduled plan of action for the following year.

15.7.2 The 5 Year Review of the Management Plan

At the end of the first five years of the duration of the management plan, an overall review of the progress made thus far seems advisable. Here, highly technical skills of evaluation will be needed. Therefore, it is proposed that the 5 year review will be prepared by an independent panel of experts appointed by the management (steering) committee. This panel of experts should cover all fields of specialization required by the projects outlined in the management plan. All annual reports should be made available to members of this panel.

They should also have easy access to all parts of the Protectorate. The panel will submit their report(s) within one month of the commencement of their contract to the management council. A re-scheduled version of the management plan will be approved by the management council and issued to the site Manager for the work in the next phase.

15.8 SUMMARY

The Zaranik Protected Area was established in 1985 (Prime-ministerial Decree 1429/1985 – amended by Decree 3379/1996). It occupies the eastern sector of Lake Bardawil on the Mediterranean coast of Sinai: total area 250 km^2 . It is an important resting area for migrating Palaearctic waterbirds: designated as an Important Bird Area, and registered in the Ramsar Convention.

Habitat types include open water, inlet (Boughaze), sabkhas, calcareous stabilized sand dunes, non-calcareous stabilized sand dunes, mobile sand dunes. The biota is rich (more than 900 species) that includes 5 endemic and 16 globally threatened species.

Human uses and development schemes outside the protectorate that may have impacts on the ecology of the area include: various forms of resource use (fisheries, agriculture, grazing, salt extraction, the El-Salam canal and land reclamation projects (c. 400,000 feddans) dependent on it, the International Highway (from Rafah to Sallum).

Lake Bardawil, including the Zaranik, produces high-quality fishery but could produce greater quantity if managed on sound environmental grounds. The extension of the protectorate to include the rest of the Lake may provide means for environmental management and sustainable development of the resources, and would fend against the likely negative impacts of forthcoming development schemes.

The long-term objectives of the conservation measures adopted in this management plan include:

to maintain and enhance the ecological and landscape values of the site,

to conserve available resources of the site through environmental management,

to improve the socio-economic opportunities of the local population,

to develop public awareness and participation in nature conservation,

to resolve existing legal conflicts, especially those of land ownership,

to expand the protectorate to include the totality of Lake Bardawil and its immediate terrestrial surroundings, with Zaranik as its core zone.

The implementation of programmes (and projects) for realising these objectives (plan of action) requires:

management bodies, which include management (steering) council (policy – supervision – review- revise plans), executive committee (assist manager). The protected area will comprise: core zone units (El-Fluseyat island, bird sanctuary, Egyptian tortoise site, marine turtles site), and buffer zone (the rest of Zaranik).

It is proposed to expand the protected area to include the whole of Lake Bardawil, in this case the Zaranik area becomes core area and the rest becomes buffer and transitional areas and be managed on ecological grounds.

The plan of action envisaged for the first three years comprise six programmes that respond to the six principal long-term objectives. Each programme consists of a number of projects.

I- Programme: to maintain and enhance the ecological and aesthetic values of the site. It comprises 7 projects: 1- implement a scheme of zonation, 2- establish referral collections, 3- establish a wild life clinic, 4- take *ex situ* measures of Ilspecies conservation, 5- establish a system of data management, 6-establish an environment monitoring system and 7- initiate a programme of research.

Estimated costs for the three years are US$ 2,855,000.

II- Programme: to conserve site resources through environmental management, comprises 2 projects: 1- improve the situation of law enforcement and 2- develop and maintain conditions for improvement of fish production.

Estimated costs for the three years are US$ 170,000.

III- Programme: to improve socio-economic opportunities for local population, comprises 4 projects: 1- initiate capacity building schemes, 2-develop ecotrouism, 3- develop alternative income-generating schemes and 4- fund raising.

Estimated costs for the three years are US$ 470,000.

IV- Programme: to develop public awareness and participation in nature conservation, comprises 3 projects: 1- raise level of public awareness, 2- initiate publicity programmes and 3- involve local populations in management.

Estimated costs for the three years are US$ 46,000.

V- Programme: to resolve conflicting legislations, comprises one project: revise legislative and institutional aspects.

Estimated costs are US$ 20,000.

VI- Programme: to expand the protectorate to include the totality of Lake Bardawil and its immediate surroundings, comprises 2 project: 1- survey of Lake Bardawil and its immediate surroundings and 2- take legal steps to declare Lake Bardawil part of the protected area.

Estimated costs for the three years are US$ 205,000.

15.9 REFERENCES

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Shaker, F. A.; El-Kholy, E. S.; Abulzahab,T. A. and Fathy, M. A. 2000. Socio-economic Development for Zaranik Protected Area. MedWetCoast Project, Egypt. Envir. Aff. Agency (EEAA), Cairo, 64 pp.

1- *General Characteristics*

Northern Sinai, in which Lake Bardawil occurs, occupies about 8000 km^2, or 13% of the area of Sinai Peninsula. Lake Bardawil is mainly a flat low lying plain, bordered from the north by Sinai Mediterranean coast, from the south by a sand dune belt which extends inland to the region of fold and anticlinal hills, from the west by the Tineh Sabkha flat constituting eastern margin of the Nile Delta plain and from the east by Arish-Rafah sector. Seawater enters this lake through two artificial tidal inlets (270 and 300 m wide and 4-7 m deep); they are maintained open by periodic dredging. The third natural eastern inlet of Zaranik is now occasionally closed by silting. The bar separating the lake from the sea is arc-shaped, 300-1000 m wide. Its highest point is El-Kals (Mount Cassius), a 60 m high dune located about midway. Sediment types distribution at a benthic depth of 0-20 cm indicated that the bottom of this lagoon is sandy on the periphery, clayey sand covers most of its area, and silty clay is found in its deepest parts.

Several geomorphic and landform features produced by marine and aeolian processes occur in Bardawil lagoon. These include: shore landforms represented by foreshore slope, backshore flats, playas, sand sheets and dunes; lagoonal landforms represented by the Bardawil lagoon, islands, inlets, barrier sand flats, and sabkhas.; and aeolian landforms represented by the sand accumulation and sand dunes. Considering these landforms and the biota that inhabit them, 6 major habitat types are clearly distinguished in Lake Bardawil: Open water, salt marshes, Saline sand flats, sand hillocks, stabilized sand dunes, inter-dunes depressions, mobile sand dunes and mud flats.

The Mediterranean coastal land of Egypt belongs to the dry arid climatic zone of Koppen's classification. In general, the study area has a narrow range of variation for most of the climatic variables. The mean annual temperature varies between 20.5 °C at El-Arish and 21.1 °C at Port Said. Annual evaporation rate varies between 4.5 mm day^{-1} at El- Arish and 6 mm day^{-1} at Port Said. The distribution of the mean annual rainfall in Egypt shows a maximum close to the Mediterranean coast (192.1 mm $year^{-1}$ at Alexandria, 104.7 mm $year^{-1}$ at El-Arish) and then decreases rapidly towards the south. The mean annual total sky cover varies between 1.6 oktas in Port Said and 2.5 oktas in El-Arish. The mean scalar wind speed varies between 4.6 knots in El-Arish and 9.0 knots in Port Said.

Results of the water balance in Zaranik Wetland indicate the following: 1- rainfall represents < 3 % of the total inflow, 2- groundwater contribute < 2 % of the total inflow, 3- total water inflow represented by rainfall and groundwater is about 24.4 10^6 m^3 yr^{-1}, 4- evaporation losses represent about 54.7 % of the total outflow, 5- salt water requirement represents about 45.3 % of the water

outflow, 6- water moves always from the sea towards the wetland, 7- water in the wetland goes below sea level with depths range from –17.6 in January to –32.3 cm in July and 8- water movement below the sea level is not observable (the rate is less than 1 cm day^{-1}), wave movement recovers this daily draw down.

Land degradation and desertification in the northern Sinai have been severe in the last century. The landscape and native vegetation have been significantly altered by agriculture, livestock overgrazing, wood cutting, introduction of exotic species, urbanization and its attendant effects, and military activities.

2- *Water Properties*

The water temperature values in Lake Bardawil during 2004 varied between 11.6 ^{0}C - 33.2 ^{0}C with an annual average value of 21.5 ± 6.5 ^{0}C. Total dissolved solids varied between 38.9 to 75.3 g/l with an annual mean of 53.3 ± 2.7 g/l. Electrical conductivity values varied between 50.8 - 110.2 mS/cm with an annual mean of 70.7 ± 3.1 mS/cm. Salinity ranged between 38.5 - 74.5 ‰ with an annual mean of 50.9 ± 2.9 ‰. It is worthy to mention that, the lowest values of TDS, EC and salinity were observed at Boughaze area, while their highest values were observed at the most western part of the lagoon.

The obtained data for oxygen properties (DO, BOD and COD) showed that DO values were almost higher than the corresponding BOD and COD values indicating good water quality. Their annual mean values were 7.3, 2.9 and 5.2 mg/l respectively. The higher BOD and COD values found in El-Telul area were due to fishermen tailings.

Major anions (bicarbonate, chloride and sulphate) were found in the ranges of 120 - 220 mg/l, 21.0 - 46 g/l and 2.9 – 6.6 g/l, respectively. On the other hand, major cations (calcium, magnesium, sodium and potassium) were found in the ranges of 441 - 1200 mg/l, 1.53 – 3.11g/l, 11.7 – 25.5 and 381 - 1032 mg/l, respectively. The lowest values of major cations and anions were observed at Boughaze area, while their highest values were observed at the most western part of the lagoon.

Nutrient salts had the decreasing order of SiO_2 > NH_4^+ > NO_3 > PO_4 > NO_2 with annual mean values of 1100, 48, 42, 35, 4.5 µg/l respectively. Their values were found in the ranges of 0.3 – 3.01 mg/l, 9 – 138, 13 – 89, 10 – 90 and 0.0 – 19.2 µg/l respectively.

Heavy metals values were found in the ranges of ; 790 - 200, 95 - 480, 17 - 80, 9 - 53 and 6 - 25 µg/l for Fe, Zn, Mn, Pb and Cu respectively. The annual mean values of studied heavy metals had the decreasing order of Fe > Zn > Mn > Pb > Cu with annual mean values of 444, 166, 40, 16, 11 µg/l respectively, which are below the standard permissible values cited by World Health Organization (WHO) and European Economic Community (EEC).

3- *Sediment Properties*

Sediments in Bardawil Lagoon consist mainly of sand (72 %), mud (19 %) and very little amount of gravel size (9 %). In general, sediments of Boughaze area maintained the highest sand fractions (98.1 %), followed by low gravel percentage (1.9 %) and complete absence of mud fractions. Meanwhile, the lowest sandy fractions were found in eastern part of the lagoon (61.2 %) with highest mud fractions (27.5 %) apparently attributed to movement of mud, which resulted from dredging processes at Boughaze.

Sediments of Bardawil lagoon mostly lie in the alkaline side except in hot months (June – August) when it lies in acidic side. The pH values are in the range of 6.47 - 7.92 with an annual average of 7.33. The organic matter content varied in the range of 0.9 - 13.3 % with annual average value of 4.5 ± 0.06. Carbonate contents varied in the range of 4.0 - 37.9 % with an annual average of 22.8 ± 0.6 %.

Exchangeable nutrient salts had the decreasing order of NH_4^+ > PO_4 > NO_3 > NO_2 with annual mean values of 108, 4, 3 and 0.54 μg/g, respectively. Their values were varied in the ranges of ; 7.4 – 327.9, 1.45 – 9.5, 0.82 – 5.59 and 0.06 – 1.54 μg/g respectively.

Heavy metals values were found in the ranges of 2.92 – 7.85 mg/g, 115 - 235, 26 - 51, 4.3 – 9.3 and 11.7 – 22.1 μg/g for Fe, Zn, Mn, Pb and Cu respectively. The annual mean values of studied heavy metals had the decreasing order of Fe > Mn > Zn > Pb > Cu with annual mean values of 5.33 mg/g, 170.8, 34.2, 17.3, 6.3 μg/g respectively, which are below the standard permissible values cited by World Health Organization (WHO) and European Economic Community (EEC).

4- *Flora and Vegetation*

A total of 136 species belonging to 109 genera and 42 families were recorded in Lake Bardawil. Gramineae had the highest contribution (12.5%) followed by Chenopodiaceae (11.0%). Sixty-nine species were recorded only in Lake Bardawil (about half of the recorded species in this lake) and not in the other northern lakes (Mariut, Edku, Burullus and Manzala), of these; 25 species are annuals and 44 species are perennials.

Seventy-nine species (58.1% of the total recorded species) are perennials, and 57 species (41.9% of the total recorded species) are annuals. On the other hand, 104 species (76.5% of the total recorded species) are natural plants, 27 (19.9%) are terrestrial weeds, 4 (2.9%) are aquatic weeds and only one species (0.7%) is escaped from cultivation. Therophytes are the most represented in Lake Bardawil, followed by chamaephytes, geophytes–helophytes, hemicryptophytes, phanerophytes, parasites and hydrophytes.

Five species are cosmopolitan. Sixty species (44.1% of the total recorded species) are mono-regionals: 42 species of which are Saharo-Arabian, 12 species are Mediterranean taxa which are Saharo-Arabian taxa penetrating other

territories, 23 species are Mediterranean taxa penetrating other territories. Twenty one species are pluri-regionals: 14 species of which are Saharo-Arabian taxa penetrating other territories, 18 species are Mediterranean taxa penetrating other territories. Compared with the other northern lakes, the vegetation of Lake Bardawil has a relatively high number of endemic species (5 species).

Regarding the national distribution of species allover Egypt, 36 species have a wide national distribution (recorded in ≥ 8 out of 12 regions), of which 8 species were recorded in all the 12 regions. Twenty-eight species are very common, while 58 are common, 33 are rare and 17 are very rare.

According to the IUCN Red List categories, 6 threatened species were recorded in Lake Bardawil: 4 of which are categorized as endangered (*Astragalus camelorum, Bellevalia salah-eidii, Biarum olivieri* and *Salsola tetragona*). One species is indeterminate (*Lobularia arabica*), while another one is rare (*Iris mariae*). In addition, 5 species (3.7% of the total recorded species) are endemic taxa: *Zygophyllum album, Astragalus camelorum, Allium papillare, Bellevalia salah-eidii* and *Iris mariae.*

Four major zones were recognized in Lake Bardawil (sand bars, islets, southern shores and open water zones). The southern shores have the highest number of species (116 species: 85.3% of the total recoded species), followed by the islets (107 species: 78.7% of the total recoded species), while the open water zone has only 3 species (*Cymodocea nodosa, Halodule uninervis* and *Ruppia cirrhosa*)

The application of the agglomerative clustering technique on the plant assemblages of the 6 habitats and the similarity ordination indicate a distinction of 4 clusters. Cluster A includes communities of stabilized sand dunes and inter-dunes depressions, cluster B includes community of saline sand flats and hummocks, cluster C includes communities of open water and wet salt marshes and cluster D includes community of mobile sand dunes.

The application of TWINSPAN on the cover estimates of 45 species recorded in 150 stands in Lake Bardawil led to the recognition of nine vegetation groups. The application of DCA on the same set of data indicates a reasonable segregation among these groups: *Ruppia cirrhosa-Cymodocea nodosa* group, *Halocnemum strobilaceum* group, *Zygophyllum album* group, *Nitraria retusa* group, *Stipagrostis plumosa-Retama raetum* group, *Panicum turgidum-Thymelaea hirsuta* group, *Artemisia monosperma* group, *Asparagus stipularis* group and *Stipagrostis scoparia-Calligonum plygonoides* group.

Salinity, moisture content, calcium carbonates and disturbance are among the most important environmental factors that affect the distribution and abundance of plant species in Lake Bardawil. Environmental factors affecting the vegetation in Lake Bardawil are typical of those known to control halophytes and psammophytes. The decrease in moisture, changes in salinity

and soil texture are the main factors operative in the successional process of the vegetation of this lake , depending on the regional and local conditions of topography and landforms.

Seventy seven species in Lake Bardawil (56.6% of the total recorded species) have at least one aspect of environmental importance. 55.9% of the environmentally important species are sand controllers (e.g. wind breaks, sand binders and hummock formers), followed by shaders (13.7%), segetal weeds (8.8%), ruderal weeds (7.8%) and weed controllers, parasites and nitrogen fixers (2.9%). In addition, 99 species in Lake Bardawil (72.8% of the total recorded species) have at least one aspect of the potential or actual economic uses. The domestic and wild animals may graze and browse 76 species in Lake Bardawil (76.8% of the total economic species). Fruits, flowers, vegetative and ground parts of 21 species (21.2% of the total economic species) are eaten by the local inhabitants in the study area. Twenty-nine species (29.3% of the total economic species) are subjected to cutting for fuel. Local inhabitants, usually use the dry parts and cut green plants when they can not find dry ones. Most of the shrubby species are cut and harvested for fuel such as *Tamarix* trees, *Arthrocnemum macrostachyum* and *Sarcocornia fruticosa* (Shaltout & Al-Sodany 2000). The timber plants are limited allover Egypt: in Lake Bardawil only two species (2% of the total economic species) are suitable as timber such as *Phoenix dactylifera* and *Tamarix* trees. Twenty-one species (21.2% of the total economic species) are of several traditional uses.

5- *Phytoplankton and Periphytic Algae*

241 phytoplankton species were recorded in Bardawil Lagoon during the period from 1985 to 2002; diatoms were represented by 159 species, followed by dinoflagellates with 53 species. Cyanphytes, chlorophytes and chrysophytes were lesser recorded, and represented by 15, 8 and 4 species, respectively. Among the 241 recorded species, only 12 were common and documented in all investigations, while 56 ones were considered as new species that invaded the lagoon. The species belonging to Euglenophyceae and Chrysophyceae were sporadic, while the cryptomonodales were perennial species. It is noted that the species diversity of phytoplankton is high near the inlets compared with the center of the lagoon; this decrease is obviously related to the increase in salinity. During the period from 1969 till 2002, diatoms were the most comman group in Bardawil Lagoon. It constituted more than 60% of the total phytoplankton species and 30% of its density.

The majority of chlorophyll *a* values during the period from 1985 to 2002 were lower than 1 $\mu g\ L^{-1}$. These values indicate, to some extent, that Bardawil Lagoon is an oligotrophic ecosystem.

The epiphytic algal species in Bardawil Lagoon of both plants *Cymodocea nodosa* (Ucria) Ascherson and *Ruppia cirrhosa* (Petagna) Grande, approximates 121 species belonging to 42 genera and 3 classes. Many of these

species are known as attached species in both marine and fresh waters. 99 diatom species represent 77.9% of the total number of epiphytes species were recorded. The highest epiphytes standing crop of 23751.7 x 10^4/ g dry wt was reported during summer, while the lowest one (1553.8 x 10^4/ g dry wt) was found during autumn. The epiphytic algae are very rich in chlorophyll *a* compared with phytoplankton in Bardawil Lagoon. The highest chl *a* value 2379.9 µg gm dry wt was detected at Rabaa, while the lowest value (161 µg gm dry wt) was found at Zaranik during summer.

The qualitative study on the epipelic diatoms community of Lake Bardawil revealed that a total of 192 species belonging to 3 classes were identified. Qualitatively, diatoms were the most important group; 146 species representing 76.1% of all epipelic species. Cyanophytes ranked the second predominant position with relative occurrence of 21.4 %, while dinophytes were very scarce; their relative occurrence was 2.6 %. The diversity of the diatom flora was much higher near the inlets than in the center of the lagoon; the decrease in the number of species is obviously related to the increase in salinity southwards.

6- Bacteria and Actinomycetes

The majority of aquatic bacteria are motile, mainly by flagella, but some by creeping along solid surfaces. Bacteria may live as plankton in water or growing on some solid substrates, such as detritus. The total viable aerobic heterotrophic bacterial count in the water of Lake Bardawil (in terms of colony forming units: cfu) varied between a minimum of 24 x 10^3 cfu ml^{-1} in April and a maximum of 569 x 10^3 cfu ml^{-1} in October. In sediments, it varied between 151 x 10^3 cfu g^{-1} in February and 6281 x 10^3 cfu g^{-1} in June. The annual mean in water was 238 x 10^3 cfu ml^{-1}, compared with 2663 x 10^3 cfu g^{-1} in sediments. The bacterial count in sites dominated by seagrass *Ruppia cirrhosa* was significantly higher than those in the bare sites. In general, Benthic bacterial activity in Lake Bardawil is positively correlated with the seagrass production, due to the high input of organic matter by the seagrass

The ammonifying bacterial count in water varied between a minimum of 131 cfu ml^{-1} in April and a maximum of 1171 cfu ml^{-1} in August; while in sediments it varied between 4207 cfu g^{-1} in February, and 17946 cfu g^{-1} in August. The annual average was 372 cfu ml^{-1} in water and 8581 cfu g^{-1} in sediments. In water, the ammonium oxidizing bacterial count in water varied between a minimum of 4 cfu ml^{-1} in August and a maximum of 153 cfu ml^{-1} in April, with an annual average of 78 cfu ml^{-1}. In sediments, the ammonium oxidizing bacterial count varied between a minimum of 11 cfu g^{-1} in August and a maximum of 1180 cfu g^{-1} in October, with an annual average of 599 cfu g^{-1}.

In general, nitrite oxidizing bacterial count was lower than ammonifying bacterial count in both water and sediments. The mean count in water varied between a minimum of 8.0 cfu ml^{-1} in April and a maximum of 25.2 cfu ml^{-1} in

August; while in the sediment it varied between 8.0 cfu g^{-1} in April and 33.3 cfu in October. The annual average was 15.2 cfu ml^{-1} in the water and 21.7 cfu g^{-1} in the sediments.

The identification of aerobic heterotrophic species indicated that the predominant genera in water of Lake Bardawill were *Listeria, Bacillus, Corynebacterium, Streptococcus, Staphylococcus, Aeromonas, Vibrio, Pseudomonas, Pasteurella, Achromobacter, Moraxella, Branhamella* and *Neisseria*. Sediments of Lake Bardawil were inhabited with genera not represented in water such as *Clostridium, Erysipelothrix, Agrobacterium, Micrococcus* and *Flavobacterium*

Nitrification activity in the sediments of Lake Bardawil reached a maximum of 4.3 µg-N-NO2 g^{-1} dry soil h^{-1} in October, while it was undetectable during August. This was confirmed by the increase of ammonifying bacterial count in autumn and its decrease in summer. Measuring ammonification, nitrification and exoenzymatic bacterial activity in sediment of Lake Bardawil demonstrated that *Ruppia cirrhosa* exerted a great effect on the nitrogen cycle by the decomposition of organic matter, direct uptake of NH_4 and NO_3, thereby reducing nutrient concentrations in water.

The mean exoenzymatic bacterial activity varied between a minimum of 0.4 µmol cm^{-3} min^{-1} in April and a maximum of 10.2 µmol cm^{-3} min^{-1} in August, with an annual mean of 0.7 µmol cm^{-3} min^{-1}. There was a higher significant difference between bare sites and seagrass dominated sites, this was confirmed by increase higher aerobic heterotrophic bacterial counts in seagrass beds than in bare sites.

The seasonal averages of bacterioplankton biomass were ranged between 6.2 mg m^{-3} in winter and 156.7 mg m^{-3} in summer. Spatial and temporal variation in bacterioplankton biomass correlated significantly with the development cycles of phytoplankton and water temperature ($r = 0.87$).

The number of total coliforms, faecal coliforms and faecal streptococci, as bacterial indicators in the eastern sector of Lake Bardawil, are more than the western sector. This reflects the high load of bacterial pollution due to the activities of fishermen and their presence to the east, particularly near El-Telul fish marketing.

Edwardsiellosis caused by *Edwardsiella tarda*, is a subacute to chronic disease for variety of fish species. On the other hand, *Edwardsiella tarda* can pose a health threat to humans, usually manifesting itself as gastroenteritis and diarrhoea; however, extra intestinal infections can produce a typhoid-like illness, meningitis, peritonitis with sepsis, cellulites, and hepatic abscess. The eastern sector of Lake Bardawil attained also the highest numbers of *Edwardsiella tarda* (11 cfu 100 ml^{-1} in winter and 615 cfu 100 ml^{-1} in summer), while the western sector attained the lowest (7 ml^{-1} in winter and 220 cfu 100 ml^{-1} in summer).

Fifteen strains of actinomycetes from the water of Lake Bardawil, nine of them were identified as *Streptomyces*. Five isolates (three of them were *Streptomyces*) exhibited antagonistic activity against *E. coli* and *Edwardsiella* isolated from the water of this Lake. Seasonal average of actinomycetes counts indicated that summer records fluctuated more than the winter records. On the other hand, the western sector maintained the highest averages of actinomycetes compared with the eastern sector.

7- *Zooplankton*

A total of 58 zooplankton species were recorded from 12 sampling sites in Bardawil Lagoon during 2002 – 2003. Copepoda was the most abundant group, contributing 69.9 % of total zooplankton density. Zooplankton reached the highest density at one station during summer (198,500 ind. m^{-3}). Protists (23 species), made up 10.3 % of total zooplankton. Winter was characterized by the highest standing crop. The dominant and common zooplankton species in 1985; mainly *Tintinnopsis labiancoi* (Ciliophora) and *Acartia clausii* (Copepoda) were replaced by *T. tocantinensis* (Ciliophora) and *Oithona nana* (Copepoda). 21 zooplankton species were newly recorded in the Lake. A few species occurred all-over the whole Lagoon; *Oithona nana*, *Centropages ponticus* and *Euterpina acutifrons* (Copepoda), *Tintinnopsis tocantinensis* (Ciliophora) and *Limacina inflata* (Pteropoda), while the others were confined to restricted areas.

8- *Benthic Invertebrates*

Meiobenthic community in Lake Bardawil during 2002/03 consisted of 20 species belonging to four groups namely: Foraminifera (4 species), Ostracoda (2 species), Nematoda (3 species) and Copepoda (3 species). Nature of the sediment and organic matter were the main factors affecting the meiofaunal abundance and distribution. Anthropogenic activities (intensive fish trawling and artificial inlets) seem to affect the distribution of total meiobenthos.

Macrobenthic community during 2004 comprised 52 species belonging to five phyla; Coelenterata, Annelida, Arthropoda, Mollusca and Echinodermata. The abundance of macrobenthic species was closely correlated with nature of bottom sediments, organic matter and salinity. The long-term changes in macrozoobenthos density of Lake Bardawil (1984- 2004) showed a remarkable decrease from one year to another, that is attributed to changes in fish community structure. However, a remarkable increase in population density of Mollusca was recorded during 2004, apparently because of declining of *Sparus aurata* production, which is mainly a bottom feeder that depends mainly on Mollusca in their diet.

9- *Fishes and Fisheries*

Lake Bardawil is so far the cleanest marine water body in Egypt, as well as in the entire Mediterranean region. It is an important source of local fishery in north Sinai and the country.

Fish species inhabiting Bardawil Lagoon originate from the Mediterranean Sea and Red Sea via Suez Canal. However, the pronounced fluctuations in the hydrographic and biological conditions prevailing in the Lagoon (strong seasonal and diurnal changes in salinity and temperature) limit the number of species that are capable of thriving there to a few dozens only. The species found are by nature eurytopic, especially in their tolerance to both low and high salinities. Sixty species of fishes were collected from the lagoon during 1970s, but recently during 2000s, 44 species only were listed. The Red Sea-origin fishes in Bardawil constitute about 25% of the total recorded species.

The common commercial fishes of the Bardawil Lagoon are the gilthead bream (*Sparus aurata*), grey mullets (Mugilidae), the sea bass (*Dicentrarchus labrax*) and the common sole (*Solea solea*).

The fish catch was about 196 tons during 1920s and increased gradually to reach 371 tons in 1930s, and *Mugil cephalus* and *Liza ramada* were the most important species in catches during this period. During 1960s, the production average reached approximately 2310 tons per year and the catch was composed mainly of the gilthead sea bream, with an average yield of about 48.49% of the total catch. During 1970s, the catch varied from 900 in 1971 to 2650 tons in 1977, and showed considerable variations in the species composition. These variations reflect the influence of three main factors: 1. changes in the salinities prevailing in the Lagoon; 2. increase in fishing effort; 3. new fishing regulations introduced in years 1973-1975. A striking decrease in the catch of the gilthead bream (*Sparus aurata*) has been detected in the years 1969-1971, from about 1,000 tons in 1969 to only 180 tons in 1971; one year after the 1970 peak of high salinities. It is assumed that the abnormally high salinities prevented both the adult and the young fish from settling in the Lagoon.

On the other hand, there was another dramatic change in the catch composition of the lagoon during the last two decades. Crustaceans (shrimps and crabs) production has greatly increased in the lagoon, reaching about 60 % of the total catch in 2005, affecting the catch of other economic fish species like sea bream and sea bass. During 1980s, Sparidae (*Sparus aurata*) constituted about 60 % of the total catch of the lake. This catch decreased to about 15 % of the total fish production in early 1990's and to 8.29% during 2005.

This serious change in catch composition during the last 20 years can be attributed to a number of factors including: change in ecological conditions of the lagoon, increased of fish export and the overexploitation since late 1980's up till now. These factors led to decreasing of sea bream and sea bass

production. On the other hand, the appearance and domination of crustacean species could be attributed to the dredging of inlets, which provided suitable environmental conditions that led to flourishing of their stocks and to changing in the fishing procedures in Bardawil Lagoon. Prohibition of purse-seine fishing technique in 1993 reinstated the sea grass beds in the lagoon, which represent a suitable ecological niche for shrimp .The appearance of crustacean species led to introduction a new fishing technique to catch them (kalsa fishing technique or trawl nets). This fishing method was very destructive, and contributed to catch the fish fry of bottom feeders, like soles, sea bream and sea bass, resulting to progressive decline in their stocks.

Moreover, the great change in salinity of the lake gave the chance to several fish species inhabiting Mediterranean coast off Bardawil to find a safe shelter and rich grazing area in the lagoon. For example, several new-recorded species appeared and established themselves in the lagoon ecosystem, e.g. *Tilapia zillii*, *Siganus rivulatus* and *Hemiramphus far*. Their production increased from year to year, indicating that they found their suitable habitat in the lagoon.

Two main fishing techniques are licensed to operate in Bardawil Lagoon; namely Dabba and Bouss methods. Actually, there are also nine illegal fishing gears that operate in the lagoon in different months, according to the appearance and abundance of different species. The Dahbana gear appeared in 1988 for catching mullets, but it was a destructive gear for the sea bream juveniles. In 1995, the trawling nets were used for catching shrimps; this gear is very destructive for the juveniles of sea bream, groupers and rabbit fishes.

The catch per unit of fishing effort (CPUE) provides an indicator of the relative abundance of the different fish stocks and consequently the status of the fishery. The total CPUE in Lake Bardawil varied between a minimum of 0.9 ton/boat during 1992 and a maximum of 2.7 ton/boat during 1982. After the fishing season of 2000, a noticeable decrease in the CPUE was recorded, reflecting the fish abundance in the lagoon during the last six years.

Both of analytical models and surplus production models revealed that all fish and crustacean stocks in Bardawil lagoon are suffering from over-fishing, and the present fishing effort should be decreased to maintain these valuable resources.

Over-fishing is not the only challenge facing the development and management of Lake Bardawil fisheries, but a number of problems were identified, such as illegal mesh sizes, destructive fishing methods, high salinity, and great fluctuation in temperature, tourism and hunting as well as the biological enemies such as water birds. *Phalacrocorax carbo* causes substantial

damage to fisheries of Bardawil; where one estimate suggested that 6% of Bardawil fish production was lost by this species.The following elements could be suggested for management of the Lake: 1-regulation of mesh sizes, controlling gear types used, developing suitable fishing gear for shallow lagoons and prohibition of the destructive fishing methods, 2- monitoring salinities in various seasons and localities, 3-setting limits for a total allowable catch from the lake, 4-studying the biology, dynamics and reproductive cycle of the commercial fishes of the lake as this is an important step in establishing guidelines for fishery-regulation measures, 5-continuous clearance of inlets for exchange of water masses between the lake and the open sea and 6-revision of fisheries laws and improving the system for collecting and compiling fisheries statistics.

10- *Arachnida and Insecta*

55 spiders and scorpions, belonging to 3 orders were recorded in Bardawil area and Zaranik Protectorate during 2000. Spiders represented 89% of the total arachnids, followed by scorpions (6%) and pseudoscorpions (5%). Spiders of 20 families were collected from 13 sampled sites , the dominant families were Liocranidae, Salticidae, Lycosidae and Gnaphosidae. Collecting sites near the Visitors Centre of the protected area were the first sites in number of spider taxa and individuals.

Nine specimens of false scorpions, family *Olpiidae* were collected in August, October and November, from under stones or wet algae remnants and pitfall traps. Three scorpion species of family Buthidae were recorded in this preliminary survey. All specimens were found under stones or in big pitfall traps in August and October

About Insecta, El-Moursy *et al.* (2000) carried out four entomological expeditions to Bardawil area, between August and November 2000. 19 sites were surveyed, yielding a total of 853 specimens. 32.18 % of recorded species is accounted for only one insect order; Coleoptera or beetles (65 species), although 15 other orders are represented in the fauna. Diptera or flies (15.35%), Lepidoptera (13.86%), Hymenoptera (Ants, wasps and bees) (9.41%), Heteroptera or bugs (7.92%), Orthoptera or crickets, grasshoppers and locusts (5.94%), Neuroptera or ant-lions and aphid-lions (5.45%). The other insect orders made up 7.92% of all recorded orders. Within 202 species, there are 29 species (14.36%) very common, 7 species (3.47%) are very rare, 39 species (19.31%) are common, 67 species (33.17%) are moderately common, and 60 are rare species (29.70%).

The plant cover in Bardawil area is very important for many groups of insects, as it provides food or shelter for 69 species (34.16%). The species-richer habitat is the sand dune habitat, which is inhabited by 61 species (30.2%), while the moorland habitat is populated with 25 species (12.38%). The salty marshes and shallow waters were occupied with only 7 species (3.47%).

Furthermore, the litters, plant debris, dead trees, and organic matters were inhabited with 26 species (12.87%).

11- *Herpetofauna*

23 species of reptiles were recorded in Bardawil area and Zaranik Protectorate (14 lizard species including 7 families, and 11 genera; 4 snakes, including 2 families and 5 genera; 1 tortoise, and 3 sea turtles including 3 families and 3 genera). No amphibian was recorded, although the green toad, *Bufo viridis* could occur in the green patches of the protected area with available fresh water.

The most common species are *Acanthodactylus scutellatus, Acanthodactylus longipes, Mesalina olivieri,* and *Sphenops sepsoides.* All of them inhabiting the sand dune and sandy areas.

The gecko, *Stenodactylus sthenodactylus* is the most rare species, only one individual was collected during a study in 2000. The fan-footed gecko, *P. hasselquistii* is the first record for the Northern Sinai. Its occurrence is restricted to the salt factory in Sebeeka area, about 600 m only from the protected area buildings. It is suggested that this species was transported through the establishment of the factory in 1986.

The Egyptian tortoise is the most endangered species in the area, and the nests of that species have almost been disappeared in the few past years. Also, *Caretta caretta,* the Loggerhead Turtle and *Chelonia mydas*, the Green Turtle, *Dermochelys coriacea*, Leatherback Turtle are considered endangered species. Efforts currently aim at conservation of these threatened species.

12- Birds

Seven main avian habitats were identified in Lake Bardawil: open sea, sea inlets, open water, saline tidal shallows, shelving shorelines, salt marshes and coastal dunes. Zaranik Lagoon, as a part of Lake Bardawil, is considered to be one of the most important wetlands for waterbirds in Egypt and the eastern Mediterranean. Two hundred and forty-two species have been recorded from this Protected Area (51.5% of the total avian species recorded in Egypt). These species belong to 121 genera, 48 families and 21 orders. The well represented families are Sylviidae (26 species), Scolopacidae (25 species), Laridae (20 species), Accipitridae (18 species), Turdidae (15 species) and Anatidae (14 species). On the other hand, 18 families are represented each by only one.

Of the 242 species and subspecies recorded in Lake Bardawil, 67 are residents(26.7%). The migratory birds represent about 72.3% of the total recorded species in Zaranik. Out of 17 bird species listed in Egypt as endimic species, the collection of information about the national and world distribution of the birds in Lake Bardawil indicated the possibility of occurrence of only one endemic species: *Streptopelia senegalensis aegyptiaca*.

Many birds passing through the Zaranik Protected Area originate from the populations breeding over a large area of Eurasia and they winter across similarly huge areas of north and sub-Saharan Africa. For instance, recoveries of ringed birds show that a significant part of the migrating Herons of Zaranik come from breeding grounds around the Avov Sea and Volga. Birds of some of these species, such as grey heron *(Ardea cinerea)*, winter in Nile Delta but the majority appear to pass south to the savannas and wetlands of tropical Africa south of the Sahara.

At present, quail netting is still one of the most popular activities among the inhabitants of the northern coast of Egypt. Every autumn from early September to late October, hundreds of families stretch their nets continuously along the Mediterranean coast, migrating quails fall in these nets. Most of the trapped quails are then taken to several markets located in the coastal cities through middlemen.

Trapping birds of prey is an increasing activity among the inhabitants of the Mediterranean coast of Sinai. North Sinai with its position on the major migration routes is considered as one of the best areas in Egypt, if not in the whole Middle East, to trap falcons. The main target of this activity is the large falcons such as lanner (*Falco biarmicus*), saker (*Falco cherrug*), and peregrine (*Falco peregrinus*), the latter species is the most demanded and valued by the rich falconers from the Arab Gulf States. In North Sinai, the trapping season lasts approximately 45 days during October and November. The trapped falcons are mostly sold to falconers.

Three action areas, based on their urgency, importance and feasibility of addressing them successfully in Lake Bardawil are recommended:

1- control the capture and trade in birds of prey, 2- creating a viable protected area, and 3- continued communication and support to local authorities.

There is also a need for a more detailed long-term strategy for supportive actions that should concentrate on environmental education in the region, as well as capacity building including manpower development of local conservation authorities.

The cloacal swabs of quail and kingfisher contained three microorganisms (*Salmonella* sp., *Echerichia coli* and *Streptococcus* sp. for quail; *Salmonella* sp., *Echerichia coli* and *Staphyllococcus* sp. for kingfisher), while that of wheatear contained two microorganisms (*Echerichia coli* and *Streptococcus* sp.). On the other hand, only one microorganism was detected in the cloacal swabs of white wagtail (*Staphyllococcus* sp.) and golden oriole (*Klepsala* sp.). In addition, 9 acarina species and 7 lice species were recorded from migratory quails; while six acarina species and four lice species were recorded from farm-raised quails. Six acarina species were recorded in both migratory and farm-raised quails, while three were recorded from migratory

quails. On the other hand, 3 lice species were recorded in both migratory and farm-raised quails : *Goniocotes* sp., *Oxylipeurus dentatus, Goniodes* sp. and *Lipeurus* sp. were recorded only from migratory quails; while *Menopon gallinae* was recorded only from farm-raised quails. In conclusion, the migratory birds may act as carriers for many microbial infective agents, so great care must be taken in handling such birds once they are caught especially when they are slaughtered and prepared for the table.

13- *Mammals*

Five orders representing eleven families, sixteen genera and twenty one species of mammals were recorded in Bardawil region and Zaranik Protected Area during 2002. The long-eared hedgehog *Hemiechinus auritus* appeared to be much more widespread throughout northern Sinai than formerly believed. Fourteen species are Saharo-Sindian forms that have a wide distribution in the Sahara and southwestern Asia. Four species belong to the genera *Pipistrellus, Lepus, Rattus and Mus* are considered cosmopolitan with almost worldwide distribution. *Rhinolophus clivosus* and *Crocidura nana* are Afrotropical species .Pluriregional species, which have distribution in the Mediterranean and the Saharo-Sindian regions, are represented by *Felis silvestris*..

The mammalian species of Bardawil area are distributed among a wide range of habitats. The coastal and halophytic communities are inhabited by 21 mammalian species. The inland sand dunes come next with 10 species, while only four species were recorded from the agricultural and artificial landscape habitat types.

Four mammalian species recorded in Zaranik Protectorate are categorized locally and at the national level as threatened species. These are a rodent species, *Jaculus orientalis* and three carnivores namely: the Fennec Fox, *Vulpes zerda*, the Wild Cat, *Felis silvestris* and the Sand Cat, *Felis margarita*. Two species; *Crocidura nana* and *Dipodillus dasyurus* are rare, and in short period, may be entering the threatened species category; therefore, they need a management programme and continuous monitoring.

14- *Socioeconomic Features*

The majority of North Sinai population is mainly of Bedouin origin, although many urban inhabitants are non-Bedouin. Population number is about 305,000 individuals. The Bedouin still practice the traditional lifestyle, which is adapted to the desert environment. Some of them have settled in "rural communities". During the last two decades, there was a movement towards the cities in North Sinai, especially young and educated family members who refused to stay within the strong family boundaries and moved to the urban centers (e.g. El-Arish, Bir El-Abd, El-Telul and El-Roda).

Administratively, Bardawil area lies in the two administrative districts; El-Arish and Bir El-Abd. Both districts contrast each other; while El-Arish is the capital of the North Sinai Governorate, an urban center; Bir El-Abd is a rural center. El-Arish is divided administratively into four suburbans, four rural units and 24 Bedouin communities. Bir El-Abd administratively is one municipality with 22 rural units and 90 Bedouin communities.

Social groupings in Sinai are based on tribal affiliations. Members of clans are family up to the 5th generation. Clans make up tribes, which are above the 5th generation. There are 12 identified tribes in the region.

The land use systems and the economic activities in Bardawil Lagoon area are closely linked to the physiographic units. The population live mainly in the coastal zone. Accordingly, fishery is quite common in this part of the Governorate. Lake Bardawil forms an important fishing habitat. Rainfed agriculture is a common and important economic activity. Pasturing includes extensive grazing by camels, sheep and goats. Moreover, there is some irrigated agriculture in the district; the irrigation water is often illegally obtained from the Nile water pipeline (which provides the coastal zone with potable fresh water as far as El-Arish).

There are two types of agricultural activities in the North Sinai region; the traditional and the modern farming methods. The traditional method is applied in rainfed catchment area, where wheat, corn and barley crops are grown. These crops depend on good rainfall during the winter months to sustain a high yield. In summer, watermelon is usually grown. Date palms have an historic and cultural significance to the Bedouin tribes. Palm beaches are the symbol of North Sinai, even locations and expansion of some villages are a direct result of clusters of date palms.

Modern agricultural method with small-scale drip irrigated agriculture has developed substantially over the last ten years. Vegetables and fruits including tomatos, cucumbers, melons, watermelons and fig, as well as olive trees are grown. The fresh fruits and vegetables are cultivated in the off-season of the Delta, so these cash crops usually get high returns.

Ownership of camels and size of goat and sheep flocks traditionally assess wealth of individual Bedouin tribe members. Today, the economic reliance on livestock is waning. While they are still important in the economy of tribes, the livestock and grazing practices has been superseded by agricultural activities. As agriculture intensifies, livestock are being kept in corrals or yards in order to stop them destroying the crops. Thus, there is increasing reliance on fodder and feed, which are expensive. The overall costs and inconvenience of keeping livestock represent a major factor in the reduction of herds. The most important problems related to pasturing activities are: shortage of dry fodder, limited areas for pasturing and absence of veterinarian care.

Fishing has gained significance for the Lake Bardawil. Although it is yet considered to be one of the best quality fishing areas in Egypt, its production (about 3534 tons) accounted for 0.7 % of the national fish production in 2005. The local Bedouins have historically been involved in fishing of the lake. However, after liberation and the consequent settlements of large numbers of other tribes, fishing was taken up as a major activity. This has led to the creation of five fishing cooperatives, embracing 3,200 fishermen and there are some 1,094 boats in the area. In Zaranik Lagoon, there are about 30 fishermen with 13 small poorly equipped boats, therefore the MedWetCoast project provided them with motorized well equipped boats.

Quail hunting is a traditional activity of the Bedouins of North Sinai. In the past, quail netters were mainly farmers and fishermen. Today, because of the rapidly changing demography of the region, individuals with a variety of occupations practice quail catching. Bedouins also practice falcon trapping during the autumn bird migration period. Several techniques are employed to capture the falcons, all employing a pigeon as a lure.

All forms of hunting have been prohibited within the Zaranik Protected Area since its formal creation in 1983. Prior to this, it was forbidden to hunt certain kinds of wild animals, such as birds of prey, which was regulated by various Ministerial and Governorate decrees issued in the early 1980s.

The North Sinai Mediterranean coast is likewise under heavy pressure from tourism development. Tourism resorts are spreading east and west from El-Arish, up to the borders of the Zaranik Protected Area. There is also intensive development for tourism in northwest Sinai on the coast west of Lake Bardawil. These developments lead to complete destruction of the sites that are built on. It also leads to the degradation of vast areas surrounding them and wildlife, which are impacted by the various activities, associated with the construction and operation of these developments. Additional to the wide and long sand beach, there is a number of archaeological sites in the North Sinai. There are two historical sites within the protected area, the buried towns of El-Flusiyat (Ostracine) and El-Koyenat, dating from the Roman and Islamic periods, respectively. Other historic sites near Zaranik include Ketab El Kals (Cassius) on the sandbar separating the Bardawil Lagoon from the Mediterranean sea, Tel El-Farma (Pelusium), El-Mohammadiat and Kattiah at the western end of the Lake Bardawil.

On the other hand, traditional needlework (handicraft) for personal use and sale to merchants used to be a common activity in rural families. Today families still actively practice needlework but the young, educated girls are mainly interested in other activities. Moreover, from the main small industries are processing compressed dates, the date palm by-products and animal hair and wool. The most significant impacts of inhabitant's activities are:

- The loss of natural habitats and increased pressure on remaining wild animals and wetlands. The desert reclamation scheme will lead to the loss of important habitats for flora and fauna.
- Displacement of existing natural population and of traditional land use activities.
- Loss of known and unknown historical and archeological sites.

Participation of local people in conservation efforts is needed. Efforts should be exerted to build up local skills, interests and capacity. The proposed zoning system in the management plan of the Zaranik Protected Area, which promotes nature conservation in selected areas and human use in others and different buffer zones, should be considered for the whole Lake Bardawil.

15- *Management Plan*

The Zaranik Protected Area was established in 1985 (Prime-ministerial Decree 1429/1985 – amended by Decree 3379/1996). It occupies the eastern sector of Lake Bardawil on the Mediterranean coast of Sinai: total area 250 km^2. It is an important resting area for migrating Palaearctic waterbirds: designated as an Important Bird Area, and registered in the Ramsar Convention.

Habitat types include open water, inlet (Boughaze), sabkhas, calcareous stabilized sand dunes, non-calcareous stabilized sand dunes, mobile sand dunes. The biota is rich (more than 900 species) that includes 5 endemic and 16 globally threatened species.

Human uses and development schemes outside the protectorate that may have impacts on the ecology of the area include: various forms of resource use (fisheries, agriculture, grazing, salt extraction, the El-Salam canal and land reclamation projects (c. 400,000 feddans) dependent on it, the International Highway (from Rafah to Sallum).

Lake Bardawil, including the Zaranik, produces high-quality fishery but could produce greater quantity if managed on sound environmental grounds. The extension of the protectorate to include the rest of the Lake may provide means for environmental management and sustainable development of the resources, and would fend against the likely negative impacts of forthcoming development schemes.

The long-term objectives of the conservation measures adopted in this management plan include:

1- to maintain and enhance the ecological and landscape values of the site,
2- to conserve available resources of the site through environmental management,
3- to improve the socio-economic opportunities of the local population,
4- to develop public awareness and participation in nature conservation,
5- to resolve existing legal conflicts, especially those of land ownership,

6- to expand the protectorate to include the totality of Lake Bardawil and its immediate terrestrial surroundings, with Zaranik as its core zone.

The implementation of programmes (and projects) for realising these objectives (plan of action) requires:

1- Management bodies: management (steering) council (policy – supervision – review- revise plans), executive committee (assist manager).
2- The protected area will comprise:
   (i) Core zone units (El-Fluseyat island, bird sanctuary, Egyptian tortoise site, marine turtles site), and
   (ii) buffer zone (the rest of Zaranik).
3- It is proposed to expand the protected area to include the whole of Lake Bardawil, in this case the Zaranik area becomes core area and the rest becomes buffer and transitional areas and be managed on ecological grounds.

The plan of action envisaged for the first three years comprise six programmes that respond to the six principal long-term objectives. Each programme consists of a number of projects.

1- Programme: to maintain and enhance the ecological and aesthetic values of the site; comprises 7 projects.
   (i) Implement a scheme of zonation
   (ii) Establish referral collections.
   (iii) Establish a wild life clinic.
   (iv) Take *ex situ* measures of species conservation.
   (v) Establish a system of data management.
   (vi) Establish an environment monitoring system.
   (vii) Initiate a programme of research.

   Estimated costs for the three years US$ 2,855,000.

2- Programme: to conserve site resources through environmental management, comprises 2 projects.
   (i) Improve the situation of law enforcement.
   (ii) Develop and maintain conditions for improvement of fish production.

   Estimated costs for the three years US$ 170,000.

3- Programme: to improve socio-economic opportunities for local population, comprises 4 projects.
   (i) Initiate capacity building schemes.
   (ii) Develop ecotrouism.

(iii) Develop alternative income-generating schemes.
(iv) Fund raising.

Estimated costs for the three years US$ 470,000.

4- Programme: to develop public awareness and participation in nature conservation, comprises 3 projects.
   (i) Raise level of public awareness.
   (ii) Initiate publicity programmes.
   (iii) Involve local populations in management.

   Estimated costs for the thee years US$ 46,000.

5- Programme: to resolve conflicting legislations, comprises one project.
   (i) Revise legislative and institutional aspects.

   Estimated costs US$ 20,000.

6- Programme: to expand the protectorate to include the totality of Lake Bardawil and its immediate surroundings, comprises 2 project.
   (i) Survey of Lake Bardawil and its immediate surroundings.
   (ii) Take legal steps to declare Lake Bardawil part of the protected area.

   Estimated costs for the three years US$ 205,000.

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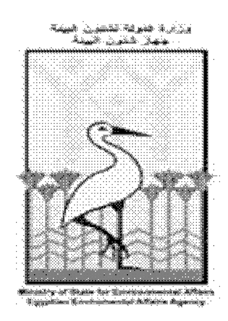
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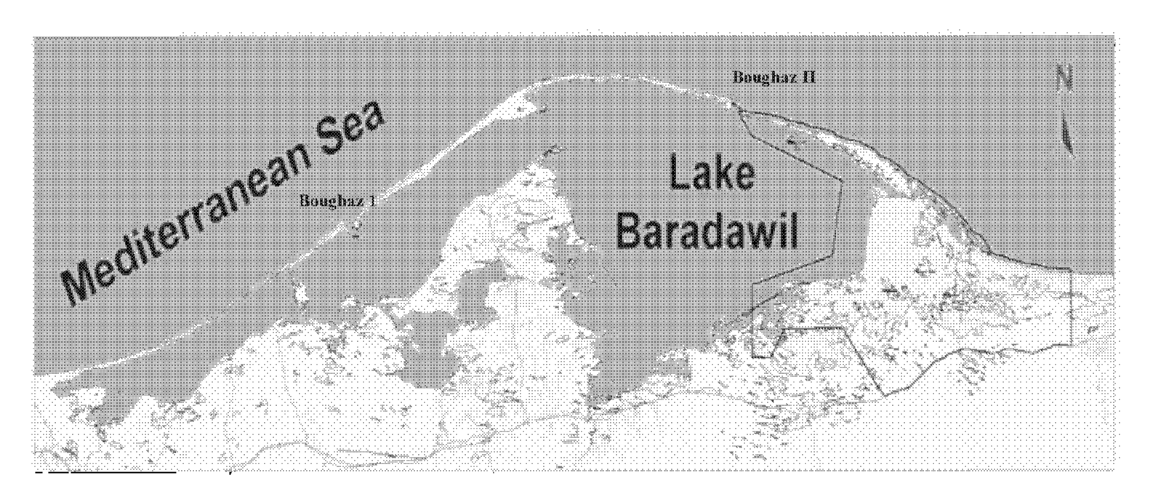
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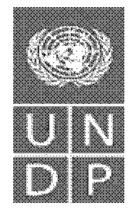
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دكتور/ كمال حسين شلتوت
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مطبوعات وحدة التنوع البيولوجى – العدد 15 – 2006









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Degrees

- **Ph. D. in 1985, from Syracuse University, N.Y., USA and Ain Shams University, joint supervision.**
- **M. Sc. in 1978, from Ain Shams University.**
- **B. Sc. in 1973, from Zoology Dept., Faculty of Science, Ain Shams University.**

Field of Research: **Environmental Sciences, Aquatic Ecology & Biodiversity.**

Published Articles: **Over 40 papers in international and local journals.**

Supervision of Theses: **Supervised more than 27 theses for M. Sc. and Ph. D.**

Membership of Societies and Organizations

Active member in 16 scientific international and local societies such as the Ecological Society of America, USA; International Center for Living Aquatic Resources Management, Philippines; the National Committee of Envir. Aff., Egypt. Acad. of Sci. and Technology.

Projects

Co- researcher of 16 scientific projects such as the Egyptian - American project for developing Lake Qarun (1973-1978); Development of Lake Manzala, under the supervision of UNEP and a Canadian company (1979-1980); American project for investigating the water quality and the effect of the industrial wastes upon three rivers system in Central New York, USA (1981); the effects of pollutants upon fauna of Lakes Manzala and Maruit (1987 - 1988); a project for preparing "Egypt Country Study on Biological Diversity", Egyptian Environmental Affairs Agency (1993-1994) with UNEP support. Through this project 8 detailed studies on species diversity of 8 taxa of freshwater organisms have been prepared. Moreover, 8 volumes on "Habitat Diversity of Coastal Lagoons and Inland Lakes" have been prepared. In addition, he joined a project for studying the Biodiversity at Gulf of Aqaba, under the supervision of Natural Protectorates Department of EEAA (1994-1995). Joined a project supported by Operational Unit for Development Assistance (OUDA) through Consulting Engineers Services for biological treatment some of wastewater discharging into Lake Manzala (2000 -2005). Joined a Project for the Conservation of Wetland and Coastal Ecosystems in the Mediterranean Region as a National Coordinator of descriptive studies of 3 protectorates (Burullus, Bardawil, Omayed) , from May 2001 until 2006.

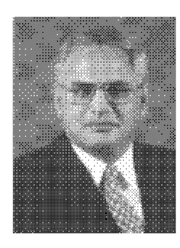
Scientific Books

Contributed in producing 3 reference books for the National Biodiversity Unit of EEAA:

1. **Freshwater Fishes of Egypt (1997).**
2. **Freshwater Molluscs of Egypt (1998).**
3. **Lake Nasser (2001).**
4. **Lake Burullus (2005).**

Awards & Certificates

1- The State-Encouragement Prize in Biology (Environmental Studies) in 1998.
2- Medal and Certificate of Appreciation from Ain Shams University in 2000.
3- Certificate of Merit as Environmental Patron from the Arab Towns Organization, Doha, Qatar in 2001.
4- Awarded MEDAL from Union of Non-Gov. Env. Societies, 2006.



Name: PROF. KAMAL HUSSIEN SHALTOUT

Current position: Professor of Plant Ecology & Head of Botany Department, Faculty of Science, Tanta University, Tanta, Egypt.

Education: Ph. D. Degree in Plant Ecology from Faculty of Science, Tanta University, Tanta, Egypt (1983).

Teaching Experience: Teaching under graduate courses such as General Botany, Structure & Function of Ecosystems, Vegetation Ecology, Wild Life Conservation, Phyto-geography, Flora, Economic Botany, Environmental Pollution, and Taxonomy of Flowering Plants; and post graduate courses such as Methods of Vegetation Analysis, Population Ecology, Phyto-sociology, and Bio-statistics.

Fields of Research Experience: Analysis, biodiversity, population ecology and conservation of the vegetation of the Mediterranean and Saharo-Arabian regions (including arid and wetlands) with special emphasis on the Egyptian and Arabian environments.

Projects: Working as research assistant, researcher and team leader in many research projects that have been carried out in the Egyptian desert and wetland ecosystems since 1975 up till now.

Trainings, Scholarships and Scientific Meetings: Attending many training courses and scholarships in Egypt, Saudi Arabia, Kenya, France and the Netherlands, as well as several national and international symposia, conferences and congresses in Egypt and abroad.

Scientific School: 30 M.Sc. and Ph.D. graduates and students in the fields of population and community plant ecology.

Councils, Committees and Societies: Member of 20 national and international councils, committees and societies in the field of Botany and Environmental Sciences.

Publications: 80 publications, in national and international specialized journals, covering many aspects of plant ecology such as:

a) Population ecology of *Thymelaea hirsuta*, a circum Mediterranean shrub of great environmental and ecomomic importance.
b) Population and vegetation ecology of the Nile Delta region, the region that has been subjected to severe environmental impact after the construction of Aswan High Dam.
c) Analysis and management of the vegetation of the Eastern and Central Saudi Arabia.
d) The primary production and diversity of the vegetation of the western Mediterranean desert of Egypt.
e) Population and vegetation ecology of the Egyptian Red Sea and eastern deserts.
f) Scientific culture, environmental awareness, environmental education and community services.

Honours and Awards:

a) State Award in Biological Sciences, from the Egyptian Academy of Scientific Research and Technology (1996),
b) First Order of Excellence, from the President of Egypt (1997),
c) Biographee in WHO'S WHO in Science and Engineering & WHO'S WHO in the World.

1- الخصائص العامة

تحتل منطقة شمال سيناء، والتى توجد فيها بحيرة البردويل، حوالى 8000 كم^2 أو 13% من المساحة الكلية لشبه جزيرة سيناء.وتعتبر بحيرة البردويل بشكل عام سهل مفلطح منخفض، يحده من الشمال ساحل البحر المتوسط، ومن الجنوب حزام الكثبان الرملية الممتدة للداخل، ومن الغرب مسطح سبخة التينة مكونا الحد الشرقى لسهل دلتا النيل، ومن الشرق قطاع العريش – رفح. ويدخل ماء البحر هذه البحيرة من خلال مدخلين صناعيين متأثرين بالنشاط المدى لمياه البحر (270 – 300م اتساع، و 4–7م عمق)؛ ويتم البقاء عليهما مفتوحين عن طريق الحفر الدورى. أما المدخل الثالث فهو مدخل طبيعى يعرف بمدخل الزرانيق ويكون مغلقاً أحياناً بتأثير الإطماء. وتمتد البحيرة حوالى 90 كم طولا ويبلغ أقصى عرض لها حوالى 22 كم ويتراوح عمق الماء بها بين 0.5 و 3 م وتصل مساحة البحيرة الى حوالى 650 كم^2 وتعتبر البحيرة أحد أهم مصادر الدخل للكثير من أبناء محافظة شمال سيناء.

أما الحزام الرملى الذى يفصل البحيرة عن البحر فله شكل قوس يبلغ اتساعه من 300 إلى 1000م، وتسمى أعلى نقطة فى هذا الحزام الكلس (جبل كاريوس)، ويوجد كثيب رملى يبلغ ارتفاعه 60م على خط يتوسط هذا الحزام. ويدل توزيع أنواع الرواسب حتى عمق يصل من صفر إلى 20سم على أن قاع هذه البحيرة رملى عند الحواف، بينما يغطى معظم القاع رمال طينية، كما يوجد الطين الطميى فى أعمق أجزائه.

يوجد فى بحيرة البردويل عدة مظاهر جيومورفولوجية نتجت عن العمليات البحرية والهوائية تشتمل على: أشكال الشاطئ الممثلة بالانحدار الشاطئي الأمامي، والمسطحات

الشاطئية الخلفية، والسبخات، والمسطحات والكثبان الرملية؛ والأشكال البحرية ممثلة بالبحيرة، والجزر، والمداخل، والمسطحات الرملية الحاجزية والسبخات. والأشكال الريحية ممثلة بالتجمعات والكثبان الرملية . ومع الأخذ فى الاعتبار أشكال الأرض والكائنات الحية التى تقطنها، حيث تتميز ستة أنواع من المواطن (البيئات) وهى: الماء المفتوح، والسبخات الملحية، والمسطحات الرملية الملحية، والنباك، والكثبان الثابتة، والمنخفضات بين الكثبان، والكثبان المتحركة والمسطحات الطينية.

ينتمى ساحل البحر المتوسط لمصر إلى المنطقة المناخية للأراضى الجافة طبقاً لنظام كوبن، وعموماً فإن منطقة الدراسة تتميز بمجال تغير ضيق فى معظم المتغيرات المناخية. يتباين المتوسط السنوى لدرجة الحرارة ما بين 20.5م^{5} عند العريش و 21.1م^{5} عند بورسعيد . ويتباين معدل البخر السنوى بين 4.5 مم يوم$^{-1}$ عند العريش و 6 مم/ يوم عند بورسعيد. ويوضح المتوسط السنوي لتوزيع المطر فى مصر وجود ارتباط وثيق بين كمية المطر والبعد عن ساحل البحر المتوسط (192 مم/ سنة عند الاسكندرية و 105 مم/ سنة عند العريش) ثم ينخفض بعد ذلك بسرعة فى اتجاه الجنوب. ويختلف المتوسط السنوي لكثافة السحب بين 1.6 اوكتاس عند بورسعيد و 2.5 اوكتاس عند العريش، بينما يتباين المتوسط السنوى لسرعة الرياح بين 4–6 عقدة فى العريش و 9 عقدة فى بورسعيد .

توضح نتائج التوازن المائى لمنطقة الزرانيق الرطبة (وهى تمثل الجزء الشرقى لبحيرة البردويل) ما يلى: 1– يمثل ماء المطر أقل من 3% من الماء الداخل إلى البحيرة،2– يشارك الماء الأرضي بأقل من 2% من الماء الداخل إلى البحيرة، 3– الماء الداخل إلى البحيرة عن طريق المطر والمياه الجوفية يمثل حوالى 24.4 مليون م^{3} /سنة، 4– يشكل الماء المفقود عن طريق البحر حوالي 54.7% من الفاقد الكلى ،5– تمثل الاحتياجات المائية لاستخلاص الملح حوالى 45.3% من الماء المفقود، 6– يتحرك الماء دائماً من البحر إلى البحيرة ،7– يوجد الماء فى البحيرة أسفل ماء البحر بأعماق تتراوح من –17.6سم فى يناير و –32.3سم فى يوليو ، 8 – حركة الماء أسفل مستوى ماء البحر غير ملحوظة (المعدل أقل من 1سم/ يوم) ، وتستعيد حركة الأمواج هذا السحب السفلى اليومى .

ويعتبر تدهور وتصحر الأراضي فى شمال سيناء شديداً خلال القرن المنصرم. حيث حدثت تغيرات شديدة في المشهد الأرضي والكساء الخضري الأصلي عن طريق الزراعة، والرعى الجائر بواسطة الحيوانات المستأنسة، وقطع الأخشاب بغرض استخدامها كوقود، وإدخال أنواع غريبة على المنطقة، والتعمير الحضري وتأثيراته، وكذلك الأنشطة العسكرية.

2- الخصائص الفيزيائية والكيميائية للمياه

خلال عام 2004 وجد ان قيم درجات حرارة المياه فى البحيرة قد تغيرت في المدى بين 11.6 – 33.2 م° بمتوسط سنوي يبلغ 21.5 ± 6.5 م°. وتروإحت قيم الأملاح الذائبة الكلية بين 38.9 – 75.3 جم/لتر بمتوسط سنوي قدره 53.3 ± 2.7 جم/لتر، بينما تغيرت قيم درجة التوصيل الكهربائى ما بين 50.8 – 110.2 مللي سيمن/سم بمتوسط سنوي 70.7 ± 3.1 مللي سيمن/سم. أما الملوحة في بحيرة البردويل فقد تغيرت في المدى بين 38.5 – 74.5 ‰ بمتوسط سنوى يبلغ 50.9 ± 2.9 ‰. ومن الجدير بالذكر أن قيم كل من الأملاح الذائبة الكلية ودرجة التوصيل الكهربائى والملوحة سجلت أعلى قيم لها في أقصى غرب البحيرة في منطقة رابعة أما أقل القيم فقد سجلت عند منطقة البواغيز.

كما تراوحت قيم الأكسيجين الذائب بين (4.0 – 10.40 مجم/لتر) بمتوسط عام بلغ 7.03 مجم/لتر. بينما تراوحت قيم الأكسجين المستهلك حيوياً بين (1.2 – 6.8 مجم/لتر) بمتوسط بلغ 2.9 مجم/لتر. وتراوحت قيم الأكسجين المستهلك كيميائياً بين (2.0 – 10.0 مجم/لتر) بمتوسط 5.0 مجم/لتر. ومن الملاحظ أن قيم الأكسجين الذائب دائماً أعلى من قيم كل من الأكسجين المستهلك حيويا وكيميائيا. كما سجلت القيم العظمى لكل من الأكسجين المستهلك حيويا وكيميائيا في محطة التلول نتيجة انشطة الصيادين فى هذه المنطقة.

وقد اختفت الكربونات تماماً في معظم المحطات خلال معظم شهور الدراسة، لكنها وصلت لأعلى قيمة لها وهي 40 مجم/لتر في محطة رابعة خلال شهر أغسطس. وتراوحت قيم البيكربونات بين (120 – 220 مجم/لتر) بمتوسط عام قدره 169 مجم/لتر.كما احتفظت محطة رابعة بأعلى قيم للكلورايد على مدار العام حيث أنها من أكثر المناطق ملوحة في البحيرة بسبب بعدها عن البواغيز وسجلت أعلى قيمة للكلورايد 46 جم/لتر خلال

شهر أغسطس بينما سجلت أقل قيمة في مياه بوغاز 1 وكانت 21 جم/لتر. وتغيرت قيم الكبريتات بين (2.9 – 6.6 جم/لتر) بمتوسط عام قدره 4.9 جم/لتر وقد سجلت أقل قيمة في محطة بوغاز 1 وأعلى قيمة في محطة رابعة.

وتراوحت قيم الكالسيوم بين 441 – 1200 مجم/لتر بمتوسط عام قدره 754 مجم/لتر وقد سجلت أقل قيمة في منطقة البواغيز وسجلت أعلى قيمة في محطة رابعة. بينما تراوحت قيم الماغنسيوم بين 1.53 – 3.11 جم/لتر بمتوسط عام قدره 2.11 جم/لتر . وتراوحت قيم الصوديوم و البوتاسيوم بين 11.7 – 25.5 جم/لتر و 381 – 1032 مجم/لتر على التوالي.

وقد أظهرت النتائج أن أعلى تركيزات للأملاح المغذية كانت السليكات الذائبة > الأمونيا > النترات > الأورثوفوسفات > النيتريتات وكانت متوسطاتها السنوية 1100، 48، 42، 35، 4.5 ميكروجرام/لتر على التوالي. كما أظهرت النتائج أن تركيزات الأملاح المغذية زادت إلى حد ما في منطقة مرسى التلول بسبب أنها أكبر مركز من مراكز تجميع الأسماك في البحيرة، ويتم إلقاء مخلفات الأسماك والمراكب مباشرة داخل هذا الجزء ولكن تأثير هذه الملوثات محدود فقط في هذه المنطقة ولم يتعداها إلى مناطق أخرى.

وكانت تركيزات المعادن الثقيلة تتدرج كما يلي: الحديد > الزنك > المنجنيز > الرصاص > النحاس، وتراوحت هذه النتائج للحديد والمنجنيز والزنك والنحاس والرصاص بين 200 – 790، 95 – 480، 9 – 53، 6 – 25 ميكروجرام/لتر على الترتيب. وجميع القيم المسجلة تعتبر أقل من النسب العيارية المسموح بها عالمياً .

3- خصائص الرواسب

يتكون قاع بحيرة البردويل في الغالب من رواسب رملية تبلغ نسبة 72 % ثم تليها الرواسب الطميية بنسبة 19 % بينما كانت الرواسب ذات حجم الحصى قليلة في الغالب وتمثل نسبة 9 %. وقد احتفظت رواسب منطقة البواغيز بأعلى نسبة من الرواسب الرملية بنسبة بلغت 98.1 % بينما مثلت الرواسب ذات حجم الحصى نسبة 1.9% مع اختفاء الرواسب الطميية تماماً. وكانت أقل نسبة للحجم الرملي في الجزء الشرقي من البحيرة بنسبة بلغت 61.2% وسجلت أعلى قيم للرواسب ذات الحجم الطميي في هذه المنطقة

بنسبة بلغت 27.5 % بسبب عمليات التجريف المستمرة لمنطقة البوغاز مما يؤدي إلى حركة الطمي إلى داخل البحيرة.

وقد تم دراسة رواسب قاع بحيرة البردويل تفصيليا خلال عام 2004، وقد اتضح ان رواسب البحيرة تقع غالبا في الجانب القلوي باستثناء شهور الصيف، حيث كانت في الجانب الحمضي، وتراوحت قيم الرقم الهيدروجيني بين 6.47 – 7.92 بمتوسط سنوي يبلغ 7.33 . أما عن تركيزات المادة العضوية فقد بلغ المتوسط السنوى لها 4.5 % وسجلت أعلى قيمة لها (13.3%) في محطة مرسى التلول. وتراوحت قيم الكربونات بين 4.0 – 37.9 % بمتوسط سنوي يبلغ 22.8 %، ونلاحظ ارتفاع نسبة الكربونات في رواسب بحيرة البردويل وخاصة في الجزء الشرقي من البحيرة بسبب وفرة أعداد أصداف الرخويات في هذه المنطقة.

تتدرج تركيزات الأملاح المغذية الذائبة على النحو التالي: الأمونيا > الأورثوفوسفات > النترات > النتريتات، حيث كانت التغيرات الشهرية لهذه الأملاح في المدى بين: 7.4 – 327.9، 1.45 – 9.5، 0.82 – 5.59 و 0.06 – 1.54 ميكروجرام/جرام وكانت المتوسطات السنوية كالتالي: 108 ، 4 ، 3 و 0.54 ميكروجرام/جرام على التوالي.

وجدت تركيزات العناصر الثقيلة في المدى بين 2.92 – 7.85 مجم/جم، 115 – 235، 26 – 51، 4.3 – 9.3 و 11.7 – 23.9 ميكروجرام/جرام لعناصر الحديد، المنجنيز، الزنك، النحاس والرصاص على التوالي. وتتدرج تركيز هذه العناصر على النحو التالي: الحديد > المنجنيز > الزنك > الرصاص > النحاس بمتوسطات سنوية كالتالي: 5.33 مجم/جم، 170.8، 34.2، 17.3، 6.3 ميكروجرام/جرام على التوالي.

4- النباتات والكساء الخضرى

تم تسجيل136 نوعاً نباتيا تنتمي إلى 109 جنساً و 42 فصيلة. وتعتبر الفصيلة النجيلية هى الأكثر تمثيلا (12.5%) يليها الفصيلة الزربيحية (11.0%) . تم تسجيل 69 نوعاً (25نوعاً حوليا و 44نوعاً معمراً) لا توجد إلا فى بحيرة البردويل مقارنة ببحيرات الساحل الشمالى الأربعة الأخرى وهى مريوط ، ادكو ، البرلس ، والمنزلة (حوالي نصف عدد الأنواع المسجلة فى البحيرة). تمثل الأنواع الحولية 71 نوعاً (58.% من الأنواع الكلية المسجلة) والأنواع المعمرة 57 نوعاً (41.9% من الأنواع الكلية المسجلة) . وعلى

الجانب الآخر ، ينتمى 104 نوعاً إلى مجموعة النباتات البرية (76.5% من الأنواع الكلية) ، و27 نوعاً إلى الحشائش ألأرضية (19.9%) ، وأربعة أنواع مائية (2.9%) ونوع واحد فقط من الأنواع الهاربة من الزراعات (0.07%) .

وتعتبر خمسة أنواع من النباتاتً عالمية التوزيع ، و60 نوعاً لها توزيع وحيد المنطقة (42 منها تمثل المنطقة العربية الصحراوية ، و12نوعا تمثل منطقة البحر المتوسط). وعلى الجانب الأخر، 45 نوعا لها توزيع ثنائي المناطق اغلبها نباتات تتبع المنطقة العربية الصحراوية لكنها ممثلة فى منطقة أخرى. ينتمى 21 نوعاً إلى مناطق متعددة : 18 نوعاً تنتمي إلى منطقة البحر المتوسط مع مناطق أخرى، و14 نوعاً تنتمي إلى المنطقة العربية الصحراوية مع مناطق أخرى . ومقارنة ببحيرات الساحل الشمالي الأخرى تحتوى فلورة بحيرة البردويل على عدد أكبر من النباتات مقتصرة التوزيع (5 أنواع).

وبمقارنة التوزيع على مستوى مصر، يوجد 36 نوعاً ذات توزيع متسع (توجد من ثمانية أو أكثر من الإثنى عشر منطقة جغرافية) ، منها 8 أنواع مسجلة فى كل المناطق الجغرافية الإثنى عشرة . وعلى الجانب الأخر يعتبر 28 نوعاً من النباتات شائعة الانتشار جداً، بينما 58 نوعاً تعتبر أنواعاً شائعة، و 33 نوعاً نادراً، 17 نوعاً نادراً جداً . وطبقاً لمراتب القائمة الحمراء التي أعدها الاتحاد الدولى لصون الطبيعة، تم تسجيل ستة أنواع مهددة بالانقراض فى بحيرة البردويل: اثنان منها معرضة للخطر، وواحد غير محدد ونبات آخر نادر. بالاضافة إلى ذلك فإن خمسة أنواع تشكل 3.7% من العدد الكلى للأنواع تعتبر أنواعاً مقتصرة التوزيع.

ويمكن تقسيم منطقة بحيرة البردويل إلى أربع مناطق كساء خضرى كبيرة وهى الحاجز الرملي، الجزر، الشواطئ الجنوبية ومنطقة الماء المفتوح. وتحتوى الشواطئ الجنوبية على أكبر عدد من الأنواع (116 نوعاً تشكل 85.3% من العدد الكلى)، يلى ذلك الجزر (107 نوعاً تشكل 78.7% من العدد الكلى للأنواع)، بينما تحتوى منطقة الماء المفتوح على ثلاثة أنواع فقط.

وقد أدى تطبيق طرائق التقسيم التجميعي والتنسيق التشابهى على المجتمعات النباتية التى تكسو البيئات الشهيرة فى بحيرة البردويل إلى تمييز أربع مجموعات: تحتوى المجموعة الأولى على مجتمعات الكثبان الرملية الثابتة والمنخفضات التى بينها، و تشمل المجموعة

الثانية مجتمعات المسطحات الرملية الملحية والنباك، والمجموعة الثالثة تحتوى على مجتمعات الماء المفتوح والسبخات الملحية الرطبة، والرابعة تشمل مجتمع الكثبان الرملية المتحركة. وأدى تطبيق إحدى طرق التقسيم (توينسبان) على تقدير الغطاء النباتي لخمسة وأربعين نوعاً نباتياً فى 150 موقعاً موزعة على البيئات المختلفة لبحيرة البردويل إلى تحديد 9 مجموعات نباتية، وبتطبيق إحدى طرق التنسيق (ديكورانا) على نفس حزمة البيانات إلى فصل واضح بين هذه المجموعات.

وتعتبر الملوحة والرطوبة وكمية كربونات الكالسيوم ودرجة الإقلاق من بين أهم العوامل البيئية المؤثرة على توزيع ووفرة النباتات فى بحيرة البردويل. وعموماً ، فإن العوامل البيئية المؤثرة على الكساء الخضرى لبحيرة البردويل هى نفس العوامل التى تحكم توزيع النباتات الملحية ونباتات الكثبان الرملية . اعتماداً على الظروف المحلية والإقليمية لتضاريس وشكل الأرض فإن نقص الرطوبة والتغير فى الملوحة والتربة هى من أهم العوامل التى تؤثر على عملية تعاقب الكساء الخضرى لهذه البحيرة.

وقد تبين أن سبعة وسبعون نوعاً فى منطقة بحيرة البردويل (56.6% من العدد الكلى للأنواع المسجلة بها) لها على الأقل أهمية بيئية واحدة . وتعتبر 55.9% من الأنواع الهامة بيئياً هي أنواع ضابطة لحركة الرمال (مصدات رياح، ماسكة للرمال ومكونة للنباك)، يليها الأنواع الجالبة للظل (13.7%) ، ثم حشائش الزراعة (8.8%)، وحشائش البيئات المستحدثة (7.8%) والأنواع الضابطة للحشائش والنباتات الطفيلية والنباتات المثبتة للنيتروجين (2.9%) . بالإضافة إلى ذلك، تحتوى بحيرة البردويل أيضا على 99 نوعاً (72.8% من العدد الكلى) ذات أهمية اقتصادية فعلية أو مدخرة واحدة على الأقل. وترعى الحيوانات البرية والمستأنسة حوالي 76 نوعاً (76.8% من العدد الكلى للأنواع ذات الأهمية الاقتصادية)، بينما يأكل السكان المحليون الثمار والأزهار والأجزاء الخضرية والأرضية لواحد وعشرين نوعاً (21.2% من العدد الكلى للأنواع ذات الأهمية الاقتصادية) . بالإضافة لذلك فإن 29 نوعاً (29.3%) معرضة للقطع كوقود، ومن المعروف أن السكان المحليون يستخدمون عادة الأجزاء الجافة لمعظم الأنواع الشجيرية التي تقطع وتجمع للإستخدام كوقود مثل الإتل ، وشنان، وحطب حدادى . أما النباتات التى تستخدم كأخشاب فهى محدودة جداً فى الفلورة المصرية عموما، وفى بحيرة البردويل يوجد نوعان فقط (2%

عن العدد الكلى الأنواع الهامة اقتصادياً) هما نخيل البلح والإتل . ويوجد حوالى 21نوعاً (21.21% من العدد الكلى للأنواع الهامة اقتصادياً) لها عدة استخدامات تقليدية.

5- الهائمات النباتية

تم تسجيل حوالى 241 نوع من الهائمات النباتية فى بحيرة البردويل خلال الفترة من 1985 حتى 2002. مثلت الدياتومات 159 نوع ثم السوطيلت 53 نوع. وكانت مجموعات الطحالب الخضراء المزرقة و الطحالب الخضراء أقل تواجدا حيث سجل لكل منهما 15 و 8 أنواع على التوالي.كما وجد أن 12 نوع فقط من بين هذه الأنواع تكرر تسجيلها في كل الدراسات التي تمت خلال هذه الفترة، بينما اعتبر 56 طحلب كأنواع جديدة فى البحيرة لم تسجل الا في الدراسات الأخيرة خلال عام 2002. كما كان التنوع البيولوجي أعلى عند البواغيز عنه داخل البحيرة و ذلك يرجع أساسا الى زيادة الملوحة داخل البحيرة. وفي المدة من 1969 حتى 2002 شكلت الدياتومات أكثر من 60% من العدد الكلي للأنواع المسجلة و حوالي 30% من المحصول القائم. وبالنسبة للكتلة الحية كانت غالب قيم كلوروفيل أ المسجلة في نفس الفترة أقل من 1 ميكروجرام/لتر مما يعكس مدى فقر البحيرة للعناصر الغذائية.

كما تم دراسة الطحالب السطح نباتية لأول مرة في بحيرة البردويل خلال عام 2002، وقد تم التعرف على 121 نوع من الطحالب الملتصقة على نباتي *Cymodocea nodosa* و *Ruppia cirrhosa* . وتنتمي هذه الأنواع الى 42 جنس و 3 رتب، وشكلت الدياتومات المسجلة (99 نوع) بنسبة 77.86% من عدد الأنواع الكلية الملتصقة. وتم تقدير أعلى محصول كلي قائم (10^4x23751.7) / جم وزن جاف) خلال فصل الصيف بينما وجد أقل كثافة (10 ^{4}x1553.8 / جم وزن جاف) في فصل الخريف.

ويعتبر قيم تركيز كلوروفيل أ للطحالب الملتصقة أعلى بكثير جدا من التى سجلت للهائمات النباتية في بحيرة البردويل. وسجلت أعلى قيمة لكلوروفيل أ (2379.91 ميكروجرام / جم وزن جاف) في منطقة رابعة في حين تبين أن أقل قيمة (161 ميكروجرام / جم وزن جاف) كانت في منطقة الزرانيق في فصل الصيف.

وفي دراسة للطحالب السطح رسوبية في بحيرة البردويل تم تعريف 192 نوع تنتمي الي 3 رتب. وقد كانت الدياتومات أهم مجموعة حيث وجد أن 146 نوع تنتمي الى هذه

المجموعة حيث كونت 76.05 % من كل الطحالب السطح رسوبية المسجلة. وكانت الطحالب الخضراء المزرقة في المرتبة الثانية بوجود نسبي مقداره 21.35% ، بينما كانت السوطيات نادرة الوجود بنسبة 2.6%.وكان تجمع الطحالب السطح رسوبية أكثر تنوعا عند البواغيز إذا قورن بداخل البحيرة و يعلل ذلك لزيادة الملوحة بأتجاه الجنوب.

6- البكتيريا والاكتينوميسيتات

معظم البكتريا المائية متحركة أساساً بواسطة الأهداب، ولكن بعضها يتحرك عن طريق الزحف على الأسطح الصلبة. ويمكن أن تحيا البكتريا طافية فى الماء أو تنمو على الأوساط الصلبة مثل الفتات. وكان العدد الكلى الحي للبكتيريا الهوائية غير ذاتية التغذية فى ماء بحيرة البردويل (على اساس الوحدات المكونة للمستعمرات) يختلف من قيمة صغرى قدرها 24×10^{3} وحدة/ مل فى أبريل، وقيمة عظمى قدرها 569×10^{3} وحدة/ مل فى أكتوبر. وفى الرواسب تتراوح القيمة بين 151×10^{3} وحدة/ جم فى فبراير، و 2681×10^{3} وحدة/ جم فى يونيو. وكان المتوسط السنوى فى ماء 238×10^{3} وحدة/ مل مقارنة بـ 2663×10^{3} وحدة/ جم فى الرواسب. كما كان العدد البكتيري في المواقع التي يسودها نبات حشيشة البحر عاليا بدرجة ملحوظة مقارنة بالمواقع التى يخلو منها هذا النبات. وعموماً، فإن النشاط البكتيرى القاعى فى بحيرة البردويل يرتبط ارتباطاً موجباً مع انتاجية حشيشة البحر بسبب التركيزالعالى من المادة العضوية الناتجة عن هذا النبات.

ويتباين العدد الكلى لبكتيريا الأمونيا فى الماء بين قيمة صغرى قدرها 131 وحدة مل$^{-1}$ فى إبريل، وقيمة عليا قدرها 1171 وحدة/ مل فى أغسطس؛ بينما يتراوح هذا العدد فى الرواسب بين 4207 وحدة/ جم فى فبراير، و 17946 وحدة/ جم فى أغسطس. يبلغ المتوسط السنوى 372 وحدة/ مل فى الماء، و 8581 وحدة/ جم فى الرواسب. أما عدد البكتيريا المؤكسدة للأمونيا فى الماء فيتراوح بين 4 وحدة/ مل فى أغسطس، و 153 وحدة/ مل فى ابريل بمتوسط سنوى يبلغ 78 وحدة/ مل ؛ وفى الرواسب يبلغ هذا العدد 11 وحدة/ جم فى أغسطس، و 1180 وحدة/ جم فى أكتوبر بمتوسط سنوى يبلغ 599 وحدة/ جرام.

وعموماً، فإن عدد البكتيريا المؤكسدة للنيتريت كان أقل من عدد بكتيريا الأمونيا فى كل من الماء والرواسب. ويتراوح العدد في الماء بين 8 وحدة/ مل فى أبريل، و 25.2 وحدة/ مل فى أغسطس؛ بينما فى الرواسب يتراوح بين 8 وحدة/ جرام فى إبريل، و 33.3 وحدة/

جرام فى أكتوبر . أما المتوسط السنوى فيبلغ 15.2 وحدة/ مل فى الماء ، 21.7 وحدة/ جرام فى الرواسب.

ويدل تعريف البكتيريا الهوائية غير ذاتية التغذية على سيادة الأجناس التالية فى مياه بحيرة البردويل: ليستيريا، باسيلس، كورينبكتيريم، ستربتوكوكس، ستافيلوكوكس، إيرموناس، فيبريو، بسيدوموناس، باستيريلا، اكروموبكتر، موراكسيلا، برانهاميلا، ونيسيريا. أما رواسب البحيرة فيوجد بها أجناس غير ممثلة فى الماء مثل كلوستيريديم، ايرسبيلوثريكس، اجروبكتيريم، ميكروكوكس، وفلافوبكتيريم.

يبلغ نشاط التأزت في رواسب بحيرة البردويل قيمة عليا قدرها 4.3 ميكروجرام نيتروجين – نيتريت/ جرام تربة جافة/ ساعة فى أكتوبر ، بينما يكون هذا النشاط غير ملحوظ فى أغسطس . ويؤكد ذلك زيادة العدد الكلى لبكتيريا الأمونيا فى الخريف ونقصه فى الصيف. ويدل قياس تكون الأمونيا والتأزت والنشاط الأنزيمي البكتيري في رواسب بحيرة البردويل على أن نبات حشيشة البحر له تأثير كبير على دورة النيتروجين عن طريق تحلل المادة العضوية، والسحب المباشر للأمونيا والنترات ، ومن ثم خفض تركيزات المغذيات فى الماء.

ويتراوح متوسط النشاط البكتيرى الأنزيمى فى بحيرة البردويل بين قيمة صغرى قدرها 0.4 ميكرومول/ سم^{3} / دقيقة فى إبريل ، و قيمة كبرى قدرها 10.2 ميكرومول/ سم ^{3} / دقيقة فى أغسطس، بمتوسط سنوى قدره 0.7 ميكرومول/ سم ^{3}/ دقيقة.كما يوجد فارق كبير بين المواقع الخالية من حشيشة البحر والمواقع التى يسود فيها هذا النبات، ومما يؤكد ذلك وجود زيادة مرتفعة فى اعداد البكتيريا الهوائية غير ذاتية التغذية فى مناطق تجمع حشيشة البحر مقارنة بالمناطق التى يخلو منها هذا النبات. وبالإضافة إلى ذلك، تتراوح الكتلة الحية للطافيات البكتيرية بين 6.2مجم/ م^{3} فى الشتاء، و 156.7مجم/ م^{3} فى الصيف. وقد وجد ارتباط موجب بين التغير الزمنى فى الكتلة الحية للطافيات البكتيرية من جانب، ودورات نمو هذه الطافيات ودرجة حرارة الماء (معامل الارتباط = 0.87) من جانب أخر.

كما تبين أن عدد الكوليفورم الكلية والكوليفورم البرازية والستربتوكوكاى البرازية كأدلة بكتيرية فى القطاع الشرقى لبحيرة البردويل أكبرمن عددها القطاع الغربى، ويعكس ذلك

الحمل الكبير للتلوث البكتيرى العائد إلى أنشطة الصيادين وكثرة عددهم فى القطاع الشرقى وخاصة بالقرب من سوق أسماك قرية التلول.

ويعتبر مرض ادواردسيليوزيس الذي يسببه ميكروب ادواردسيلا تاردا، مرض تحت حاد إلى مزمن للعديد من الأنواع السمكية. ويمكن أن يؤدى إلى مخاطر جسيمة على صحة الإنسان، وعادة ما يظهر على هيئة التهابات معدية ولسهال؛ وبالرغم من ذلك فإن الإصابات المعدية الزائدة يمكن أن تسبب مرض يشبه التيفويد، والالتهاب السحائى، والالتهاب الصفاقى مع تعفن الدم، والتهاب النسيج الخلوى والفشل الكلوى. كما يتميز القطاع الشرقي لبحيرة البردويل أيضاً بأعداد أعلى من ميكروب أدواردسيلا تاردا (11وحدة/ 100 مل فى الشتاء، و 615 وحدة/ 100 مل فى الصيف)، بينما سجل فى القطاع الغربى أقل قيمة (7 وحدة /100 مل فى الشتاء، و 220 وحدة/ 100 مل فى الصيف).

وقد تم تعريف 15 سلالة من الاكتينوميسيتات من ماء بحيرة البردويل، تسعة منها عرفت على أنها تتبع جنس ستربتوميسيس.كما أظهرت خمسة عزلات (ثلاثة منها تتبع جنس ستربتوميسيس) نشاط مضاد لبكتيريا ايشريشيا كولاى، وادواردسيلا تاردا معزولة من ماء البحيرة. وأظهر التباين الموسمي في إعداد الاكتينوميسيتات أن تسجيلات فصل الصيف تتذبذب كثيراً مقارنة بتسجيلات فصل الشتاء. وعلى الجانب الآخر، كانت متوسطات أعداد الاكتينوميسيتات فى القطاع الغربى أعلى من متوسطات القطاع الشرقى.

7- الهوائم الحيوانية

تم التعرف علي 59 نوعا من الهائمات الحيوانية في بحيرة البردويل وذلك خلال موسم 2003/2002. تنتمي هذه الانواع إلى تسع مجموعات أساسية سادتها جميعا من حيث الوفرة العددية مجموعة مجدافية الأرجل بنسبة قدرها 69.9 % من قيمة العدد الكلي للهائمات الحيوانية 0

كما تم تسجيل 23 نوعا من الأوليات، ممثلة بنسبة قدرها 10.3 % من قيمة العدد الكلي للهائمات الحيوانية و تميز فصل الشتاء بأعلى وفرة عددية من هذه الكائنات. وقد ازدهرت الهائمات الحيوانية خلال موسم الصيف، حيث سجلت أعلى وفرة عددية قدرها 198500 كائن/ م3 ،بينما كان فصل الخريف هو الأفقر بهذه الكائنات0

وأظهرت الدراسة اختلافا كبيرا في التركيب النوعى للهائمات الحيوانية على مر السنين، حيث تم استبدال الانواع السائدة عام1985 بأنواع اخرى ا والجدير بالذكر أنه تم رصد 21 نوعا من الهائمات الحيوانية لأول مرة بالبحيرة خلال عام 2003.

8- اللافقاريات القاعية

تم تسجيل عشرين نوعاً من لافقاريات القاع متوسطة الحجم (ميوفونا) فى بحيرة البردويل خلال عام 2003/2002، تنتمي معظمها لأربع مجموعات هى الفورامينيفرا (أربعة أنواع) القشريات الصدفية (نوعان) والديدان الخيطية (ثلاثة أنواع) ومجدافية الارجل (ثلاثة أنواع)، بالإضافة لثمانية أنواع أخرى تنتمى إلى الديدان الحلقية والرخويات والنمرتينيا والتارديجرادا. وقد لوحظ أن أوليات الفورامينيفرا هي أكثر المجموعات تواجداً في البحيرة تلتها القشريات الصدفية ثم الديدان الخيطية. وقد تأثرت هذه الكائنات بعدة عوامل، كان أهمها طبيعة القاع والصيد الكثيف فى بعض الأماكن.

بالنسبة للافقاريات القاع الكبيرة في بحيرة البردويل تم تسجيل 52 نوعاً من هذه اللافقاريات عام 2004، تنتمي لخمس مجموعات هى الديدان الحلقية (14 نوعا) ومفصليات الأرجل (19 نوعا) والرخويات (16 نوعا) و الجلد شوكيات (نوعان) ثم شقائق البحر (نوع واحد). وقد تأثر تواجد أنواع لافقاريات القاع الكبيرة بعدة عوامل، كان أهمها طبيعة القاع ونسبة المواد العضوية والملوحة وكذلك الصيد الجائر بطريقة الجر فى بعض الأماكن.وأظهرت دراسة التغير طويل المدى للافقاريات القاع الكبيرة في بحيرة البردويل خلال أربعة فترات جمعت عيناتها أعوام 1984 و1978/1986 و2003/2002 و2004 انخفاضاً ملحوظاً في أعداد هذه الحيوانات من عام إلي آخر بالرغم من ازدياد عدد الأنواع خصوصا تلك التى تنتمى للرخويات. ويرجع هذا الاختلاف إلى تغير التركيب النوعى للأسماك فى البحيرة وانخفاض الإنتاج الكلى لها خصوصا سمكة الدنيس والتى تمثل الرخويات المكون الأساسى لغذائها.

9- الاسماك ومصايدها

تعتبر بحيرة البردويل من أهم بحيرات مصر لكونها أقل البحيرات الشمالية تلوثا كما أنها تحتوى على أنواع عالية الجودة من الأسماك والقشريات حيث يصدر معظم انتاجها للخارج، وقد بلغ متوسط الانتاج السنوى من بحيرة البردويل فى الاعوام الاخيرة حوالى 2.3 الف طن والذى يمثل حوالى 1.5% من اجمالى انتاج البحيرات المصرية.

قديما وقبل احتلال اسرائيل لشبه جزيرة سيناء عام 1967 كانت البحيرة تدار بنظام حق الامتياز وكان السيد أبو ذكرى أشهر من قاموا بإدارة البحيرة تحت هذا النظام وتراوح إنتاج البحيرة فى هذه الفترة بين 196 طن فى عام 1920 و 1719 طن فى عام 1966 وكانت أهم الأنواع المصادة هى العائلة البورية وخاصة البورى والطوبارة. وفى عام 1979 عادت البحيرة للسيادة المصرية وأصبحت تدار بواسطة محافظة شمال سيناء ووزارة الزراعة ووزارة الدفاع والآن تدار البحيرة بواسطة الهيئة العامة لتنمية الثروة السمكية. وتراوح انتاج البحيرة فى هذه الفترة بين 1039 طن عام 1979 و 3543 طن عام 2005 ، وكانت أهم الأنواع المصادة هى أسماك الدنيس والعائلة البورية والقاروص والموسى.

وقد لوحظ تدهور حاد في الوفرة النسبية لمجاميع الأسماك المستغلة بالبحيرة فى الآونة الأخيرة علاوة على التغير الكبير فى التركيب النوعى لإنتاج البحيرة خلال العشرين سنة الماضية والذى أدى إلى سيادة القشريات وتمثيلها حوالى نصف انتاج البحيرة على حساب أنواع الأسماك الأخرى الهامة كالدنيس والبورى والقاروص. ويعود تدهور إنتاجية البحيرة إلى جهد الصيد المتزايد فى البحيرة وإلى استخدام طرق صيد مدمرة للمخزون السمكي علاوة على الشباك المخالفة والسياسة المتبعة فى عمليات تصدير أسماك البحيرة. كما يعزى التغير فى التركيب النوعى للبحيرة إلى التفاوت الكبير فى درجات الملوحة وإلى عمليات تكريك البواغيز التى غيرت الظروف البيئية للبحيرة مما جعلها مناسبة لنمو وتكاثر القشريات، كما يعزى أيضا إلى تغير أساليب الصيد فى البحيرة حيث أنه وبعد منع استخدام حرفة الشانشولا سنة 1993 أصبح قاع البحيرة غنيا بالحشائش البحرية التى تعتبر بيئة مناسبة للمراحل المختلفة فى دورة حياة الجمبرى.

وتعمل في البحيرة حرفتا صيد أساسيتين هما الدبة والبوص إلى جانب العديد من الحرف الأخرى كالسنار والجر وشباك الدهبانة وشباك الطير كما يعمل بالبحيرة أكثر من 3000 صياد. والصيد بالبحيرة موسمي حيث تتوقف جميع عمليات الصيد فى الفترة من أول شهر يناير إلى نهاية شهر مارس وقد تم إختيار هذه الشهور لأنها تتزامن مع هجرة التكاثر لأسماك الدنيس والقاروص من والى البحيرة.

وقد أثبتت جميع الدراسات التى تمت على مصايد بحيرة البردويل والتى اعتمدت على النماذج التحليلية لتقدير المخزونات السمكية وعلى نماذج فائض الانتاج لتعيين جهد الصيد الأمثل الذى يحقق أقصى انتاج مستمر أن مجاميع الأسماك والقشريات المستغلة بالبحيرة تتعرض لجهد صيد جائر، وللوصول إلى الانتاج الذى يضمن الحفاظ على الكتلة البيولوجية لهذه المجاميع مع تحقيق أقل نسبة مخاطرة يجب خفض جهد الصيد كما يجب إعادة تقييم حرف الصيد المختلفة العاملة بالبحيرة مع تحديد أنسب ماجة لاتضر بالمخزون السمكى بها.

وجدير بالذكر هنا أن جهد الصيد الجائر ليس التحدى الوحيد الذى يواجه تنمية مصايد بحيرة البردويل والحفاظ على انتاجيتها وإنما هناك العديد من المشكلات التى يمكن حصرها في: طرق الصيد المدمرة كحرفة الجر على سبيل المثال والتى تغير من طبيعة قاع البحيرة كما لاتستطيع صغار الأسماك قاعية التغذية كالدنيس والقاروص والموسى الإفلات منها كما أن جميع الشباك المستخدمة ذات فتحات ضيقة لجمع كميات أكبر من الأسماك بغض النظر عن حجمها والتى تكون معظمها لم تصل بعد إلى مرحلة النضوج الجنسى علاوة على ذلك التفاوت الكبير فى كل من معدلات الملوحة ودرجات الحرارة والذى ساهم بشكل كبير فى التغير البيئى الذى شهدته البحيرة مؤخرا كما كان للطيور المهاجرة دور بارز في تدهور إنتاجية البحيرة.

ولتنمية وإدارة مصايد بحيرة البردويل يمكن إقتراح بعض الحلول التى من شأنها الحفاظ على المخزونات السمكية بها وتعظيم إنتاجها وهى:

- تنظيم فتحات الشباك المستخدمة مع منع حرف الصيد المدمرة كالجر وغزل الدهبانة والبحث عن حرف مناسبة للصيد فى المياه الضحلة مع التحكم فى وحدات الصيد العاملة بالبحيرة

- العمل على تنظيم معدل الملوحة خلال الفصول والمناطق المختلفة داخل البحيرة
- العمل بنظام الانتاج الكلى المسموح به من البحيرة
- دراسة بيولوجية وديناميكية الأنواع ذات القيمة الاقتصادية والمستغلة بالبحيرة مع الاهتمام بدورة حياتها وديناميكية التكاثر لها حيث أن هذه المعلومات هى أساس أى معايير تنظيمية مقترحة
- الإهتمام بعمليات تطهير البواغيز والقيام بها بصفة دورية
- مراجعة القوانين المنظمة لعمليات الصيد وتفعيلها مع تفعيل دور الجهات المنوط بها تنفيذ هذه القوانين
- تحسين نظام تسجيل وحصر إحصائيات المصيد مع تحرى الدقة المتناهية فى تسجيل هذه الاحصائيات
- دراسة جميع العوامل البيئية المؤثرة فى إنتاجية البحيرة للعمل على تقليل الآثار الضارة لها

10- العنكبيات والحشرات

تم دراسة مجموعة العناكب و العقارب لأول مرة في منطقة البردويل ومحمية الزرانيق عام 2000، وقد تم تسجيل 55 نوع تنتمى الى ثلاث رتب. وقد مثلت العناكب حوالى 89% من العدد الكلى للعنكبيات، تليها العقارب بحوالى65 %، ثم العقارب الكاذبة بحوالى 5 %. وتحتاج هذه المجموعة دراسة تفصيلية أخرى موسمية حتي نستطيع أن نتعرف على كل الأنواع الممكن تواجدها في هذه المنطقة.

وعلى الجانب الأخر، تم تعريف 202 نوعا من الحشرات تنتمى إلى 16 رتبة، وذلك من خلال مسح حقلى لتسعة عشر موقع فى منطقة البردويل خلال الفترة من اغسطس الى نوفمبر 2000. وقد مثلت مجموعة الخنافس (Coleoptera) بحوالى 32,18 % (65 نوع) من العدد الكلى للحشرات جميعها، بينما مثلت مجموعة ثنائية الأجنحة (Diptera) بحوالى 15,35 % ومجموعةغشائية الأجنحة (Lepidoptera) بحوالى.13,86 % .

وقد اثبتت الدراسة ان الغطاء النباتى فى منطقة البردويل من العوامل الهامة فى توزيع الحشرات، كما انها هامة فى تغذية وحماية 69 نوعا (34و12 %). وقد وجد ان

الكثبان الرملية هى اكثر البيئات فى تنوع الحشرات حيث انها تأوى حوالى 69 نوعا (34, 12%).

ومما لا شك فيه أن تلك الأرقام لا تعبر عن التنوع الحشرى فى منطقة البردويل بسبب قصر مدة الدراسة . وبناءا على ماسبق فمن الموصى به إجراء مسح شهرى لمدة عامين متتاليين حتى يمكن إعطاء صورة حقيقية عن التنوع الحشرى فى تلك المنطقة.

11- البرمائيات والزواحف

تم تسجيل 23 نوع من الزواحف في منطقة البردويل ومحمية الزرانيق، منها 14 نوع من السحالى تنتمي إلى 7 عائلات و 11 جنس، و 5 ثعابين تنتمي إلى عائلتين و 5 اجناس، و 3 سلحفاة بحرية تنتمي إلى 3 عائلات و 3 جنس، بالاضافة الى السلحفاة المصرية البرية. ولم يسجل أي نوع من البرمائيات وان كان هناك احتمال لوجود الضفدعة الخضراء في مستنقعات المياه العذبة بالقرب من المناطق المزروعة داخل المحمية.

ومن أهم الأنواع السائدة التي سجلت سقنقر الرمال الكبير والسقنقر السينائى المخطط والسحلية الدفانة، وجميعها تعيش في المناطق الرملية خصوصا الكثبان الرملية. وايضاً من الأنواع الجديره بالاهتمام البرص واسع العين، وهذا النوع نادر جدا فى المنطقة وتم جمع عينة واحدة منه خلال فترة الدراسة كلها. أما البرص ابو كف فهو يسجل لأول مرة في منطقة شمال سيناء ولكن بالقرب من المستنقعات الملحية فقط.

أما الأنواع المهددة بالانقراض داخل مصر وعالمياً، ويجب الاهتمام بها أكثر ووضع بعض البرامج الخاصة للحفاظ عليها وتنميتها هي السلاحف البحرية كبيرة الرأس المسماة بالترسة والسلحفاة الخضراء و سلحفاة جلدية الظهر، بالاضافة الى السلحفاة المصرية البرية.

12- الطيــور

تم تعريف سبعة مواطن للطيور فى بحيرة البردويل وهى: البحر المفتوح، مداخل البحر (البواغيز)، ماء البحيرة، المسطحات المدية الملحية، الشواطئ المنحدرة، السبخات الملحية والكثبان الرملية. وتعتبر بركة الزرانيق، كجزء من بحيرة البردويل، واحدة من أهم المناطق الرطبة التى تعيش فيها الطيور المائية فى مصر وشرق البحر المتوسط. وقد تم تسجيل 242 نوعاً من الطيور فى منطقة الزرانيق (51.5% من العدد الكلى للطيور المسجلة فى مصر)، تنتمى هذه الأنواع إلى 121 جنس، و 48 فصيلة، و 21 رتبة. الفصائل

الأكثر تمثيلاً هى الفصيلة السيلفيدية (26 نوعاً)، والاسكولوباسيدية (25نوعا)، واللاريدية (20 نوعاً) والاكسبتريدية (18نوع). وعلى الجانب الآخر يوجد 18 فصيلة ممثلة بنوع واحد فقط.

ومن الأنواع المسجلة في بحيرة البردويل يوجد 67 نوعاً مقيماً، بينما تمثل الطيور المهاجرة حوالى 72.3% من العدد الكلى للطيور المسجلة فى منطقة الزرانيق. كما أن العديد من الطيور التى تمر عبر محمية الزرانيق الطبيعية أصلها من جماعات تتكاثر فى مناطق واسعة من أوروبا وروسيا وتتكاثر عبر مناطق واسعة مشابهه في شمال الصحارى وجنوبها. على سبيل المثال، يوضح اكتشاف الطيور ذات الحلقات أن جزء هام من البلشونات فى منطقة الزرانيق يأتى من مناطق تكاثر حول بحر أفوف ونهر الفولجا. ويقضي بعض هذه الطيور مثل البلشون الرمادي الشتاء في منطقة دلتا النيل، ولكن الأغلبية تمر جنوباً إلى مناطق السافانا والأراضى الرطبة فى أفريقيا الاستوائية جنوب الصحراء.

ويعتبر صيد السمان حاليا من أهم الأنشطة الشائعة بين السكان المحليين القاطنين للساحل الشمالى لمصر. وفي كل خريف من بداية سبتمبر حتى اواخر أكتوبر، تنشر المئات من العائلات الشباك على امتداد ساحل البحر المتوسط حيث يقع معظم السمان المهاجر فيها. ويرسل معظم السمان الذى يتم صيده إلى عدة أسواق موجودة فى المدن الساحلية. ويعتبر صيد الطيور الجارحة من الأنشطة المتزايدة للسكان خاصة على طول ساحل سيناء. وكما هو معروف فإن شمال سيناء بموقعها عند تقاطع مسارات هجرة الطيور تعتبر واحدة من أفضل المناطق فى مصر، ان لم يمكن فى الشرق الأوسط ككل، لصيد الطيور والهدف الرئيسى لهذا النشاط هو الصقور كبيرة الحجم مثل الصقر الحر، وصقر الغزال، وصقر شاهين (وهو أكثر الصقور طلبا وذو قيمة كبيرة لمستخدمي الصقور فى منطقة الخليج العربى). ويستمر موسم الصيد فى شمال سيناء 45 يوماً خلال شهر أكتوبر ونوفمبر حيث يباع معظم الصقور إلى مستخدميها من دول الخليج من خلال كفر سعد (محافظة الشرقية) أو ابورواش (محافظة الجيزة).

يوجد ثلاثة مهام إدارية عاجلة وذات جدوى يوصى بها لحماية الطيور فى بحيرة البردويل وهى: التحكم فى صيد وتجارة الطيور الجارحة، خلق مناطق حماية كافية للحفاظ على جماعات ذات أعداد كبيرة تساعد على استمرار حياة هذه الطيور، واستمرار الاتصال

مع الهيئات المحلية المعنية بهذا الأمر لتقديم الدعم لها. كما يوجد أيضاً حاجة ملحة لاستراتيجية طويلة المدى والتى يجب أن تركز على التعليم البيئى فى المنطقة، بالإضافة إلى تنمية الكوادر البشرية للهيئات المحلية المعنية بصون حياة الطيور.

وقد أوضحت إحدى الدراسات احتواء المسحات الشرجية لطائرالسمان وطائرصياد السمك على ثلاثة كائنات دقيقة خطيرة وهى سالمونيلا ، ايشريشيا كولاى ، وستربتوكوكس فى السمان ؛ والنوعين الأولين بالإضافة إلى ستافيلو كوكس فى صياد السمك ؛ بينما احتوى طائر أبو بليق على نوعين من الكائنات الدقيقة هما ايشريشيا كولاى وستربتوكوكس. وعلى الجانب الآخر، سجل نوع واحد فقط فى المسحات الشرجية لأبوفصادة الأبيض (ستافيلوكوكس)، وعصفور التوت (كليبسالا). وفى دراسة أخرى، تم تسجيل تسعة أنواع من القراديات وسبعة أنواع من القمل على طيور السمان المهاجرة؛ بينما سجل 6 أنواع فقط من القراديات وأربعة أنواع من القمل على طيور السمان التى تم تربيتها فى المزرعة. وبالمقارنة سجلت 6 انواع من القراديات على كل من السمان المهاجر وسمان المزرعة ، بينما لم تسجل ثلاثة أنواع أخرى من القراديات إلا على السمان المهاجرفقط. وعلى الجانب الآخر، سجل ثلاثة أنواع من القمل على كل من السمان المهاجر وسمان المزرعة، بينما سجل نوع آخر على سمان المزرعة فقط. وبناء على ما سبق يمكن القول أن الطيور المهاجرة تعمل كناقلات للعديد من الكائنات الدقيقة الممرضة، ولذا يجب أن يحذر الإنسان من الاحتكاك المباشر مع هذه الطيور عقب الامساك بها مباشرة، وخاصة حينما تذبح وتعد للأكل.

13- الثدييات

تم التعرف علي 21 نوع من الثدييات في منطقة البردويل، تنتمي إلى 5 رتب و 11 عائلة و 16 جنس وذلك خلال دراسة حقلية عام 2002. وقد وجد أن القنفد طويل الأذن هو الاكثر انتشارا فى شمال سيناء خلافا لما كان يعتقد سابقا.

وتتوزع الثدييات في منطقة البردويل على كثير من البيئات الطبيعية؛ ولكن اهمها المناطق الساحلية المأهولة بالنباتات حيث تم تسجيل حوالى21 نوعا فيها. وتأتى بعد ذلك بيئة الكثبان الرملية الداخلية حيث سجل فيها حوالى 10 انواع، بينما تم تسجيل 4 انواع فقط فى المناطق الزراعية.

وتم تصنيف أربعة أنواع من الثدييات المسجلة في منطقة البردويل على المستوى القومي كأنواع مهددة بالإنقراض وهي: اليربوع الكبير، الفنك، القط الجبلي و قط الرمال. أما الزباب القزم و جربيل واجنار فقد تم تصنيفهما كأنواع نادرة يجب الاهتمام بهما أكثر ووضع بعض البرامج الخاصة للحفاظ عليها وتنميتها حتى لا تندرج في الأنواع المهددة بالانقراض.

14- النشاط الأجتماعى والاقتصادى

أن غالبية السكان في شمال سيناء من البدو ، وهم لهم طابع تقليدي خاص في أسلوب حياتهم ومعيشتهم التي تأقلمت مع البيئة الصحراوية . ويقدر عدد السكان فى شمال سيناء بحوالى 305000 نسمة، استقر معظمهم فى تجمعات قروية. ولكن خلال العقدين الاخيرين كانت هناك حركة هجرة، خصوصا للشباب المتعلم ، الى المراكز الحضرية ومدن شمال سيناء، مثل العريش وبير العبد والتلول والروضة.

وتقع البردويل إداريا في منطقتين؛ العريش وبير العبد. وهما متناقضتان فى نواحى كثيرة، فالاولى عاصمة شمال سيناء، منطقة حضرية، اما الثانية فهى منطقة قروية. وتنقسم العريش اداريا الى أربع ضواحي حضرية، وأربع وحدات قروية واربعة وعشرين تجمع بدوي. أما منطقة بير العبد فهى تضم 22 وحدة ريفية و90 تجمع بدوى. أما داخل محمية الزرانيق فلا يوجد تجمعات كبيرة من الأفراد، وينحصرون في بعض موظفي شركة النصر للملاحات وبعض أفراد حرس السواحل.

وتؤثر بحيرة البردويل بشكل أو باخر في الناحية الاقتصادية والاجتماعية لمحمية الزرانيق، حيث أن أعداد كبيرة من الأفراد بالمنطقة تعيش حول البحيرة وتعتمد عليها كمصدر أساسي لمعيشتهم. وتعتبر مهنة الصيد وصناعة استخراج الأملاح أهم الأنشطة الاقتصادية الأساسية في المنطقة التي تدر عليهم عائدا اقتصاديا جيد، وهي تعتمد أساساً علي مياه البحيرة، أما الزراعة والرعي وصيد الطيور فتأتي في المرتبة التالية من ناحية الأهمية الاقتصادية.

ويعتمد نشاط الزراعة المحدود على مياه الأمطار، لذلك فلا يوجد حتى الآن مياه صرف زراعي تصب في بحيرة البردويل. وتنحصر زراعة المحاصيل في المسطحات الرملية بين الكثبان في المنطقة الجنوبية، وهي تشمل أساساً الشعير، الطماطم، والبطيخ، ونخل البلح. كما يوجد على نطاق صغير بعض الزراعات التى تعتمد على نظام الرى

الحديث الذى ادخل الى المنطقة بعد الاحتلال الاسرائيلى وفيه تزرع بعض الخضروات والفواكه مثل الطماطم والخيار والبطيخ والتين وشجر الزيتون.

ويستغل بعض سكان المنطقة من البدو النباتات الطبيعية في رعي بعض الحيوانات وأيضا قطع الشجيرات لإنتاج الطاقة. وتأثير الرعي الجائر واضح بشكل كبير في كثير من الأماكن داخل المحمية. ويقدر العدد الكلي للحيوانات التي ترعى داخل المحمية بحوالي 6992 حيوان تشمل 291جمل ، 3485ماعز ، 2952جدي بالإضافة إلى 264حمار . وهذا العدد يعتبر أكبر بكثير عن الحد الأقصى المسموح لقدرة النباتات على استعادة ما تفقده من هذا الرعي. ولكن هناك أمل في أن تزداد كميات العلف الحيواني الذي سوف يزرع وينتج بكميات كبيرة بعد إتمام مشروع ترعة السلام.

وقد أدى الرعي الجائر في المنطقة إلي اختفاء الغطاء النباتي علي كثير من الكثبان الرملية ، الأمر الذي يؤدي بالتأكيد إلي التغيير في التركيب النوعي للكائنات في هذه البيئات ، واختفاء بعض الأنواع وظهور البعض الأخر الذي يفضل الحياة في البيئة الجديدة المفتوحة .

وتعتبر مهنة صيد الطيور من أوسع وأقدم الأنشطة في منطقة شمال سيناء . ويستهلك البدو جزء من هذا المصيد ويعرض الجزء الأخر في السوق المحلي لمدينة العريش . وبرغم أن جميع أشكال الصيد ممنوعة تماماً داخل المحمية ، إلا إنه في عام 1989 قدر مصيد السمان من علي طول شاطئ المحمية [17 كم] بحوالي 20400 طائر ، وأن كان هذا العدد قد قل كثيراً خلال السنوات الأخيرة . ويصطاد بدو شمال سيناء ايضاً بعض الطيور للاتجار بها مثل صقر الجراد أو صقر شاهين، حيث يقدر ثمن الأخير بحوالي 4800 إلي 6500 دولار عندما يتم تسويقه خارج منطقة سيناء، وغالباً ما يجد طريقه إلي دول الخليج العربي.

وتمارس حرفة الصيد في المياه المفتوحة لبحيرة البردويل. ويُحدد مواعيد الصيد في البحيرة بقرار يصدره المحافظ سنوياً لتنظيم إدارة الصيد بالتنسيق مع مدير البحيرة التابع للهيئة القومية لتنمية الثروة السمكية بالمحافظة. ويتم تحديد عدد أيام الصيد من عام لأخر حسب حالة البحيرة؛ فكانت أقلها عام 1992 حيث وصلت إلي 135يوم، أما أقصاها فكان عام 1989 حيث حددت بحوالي 210يوم. وفي الأعوام الأخيرة كانت تصل إلي 180يوم.

وعموماً فإن البحيرة غالباً ما تغلق أمام عمليات الصيد لمدة أربعة شهور في العام؛ من يناير حتى إبريل. ويقدر عدد الصيادين بحوالى 3200 صياد، كما يوجد حوالى 1094 مركب فى المنطقة.أما الذي يعيشون داخل حدود المحمية فيقدروا بحوالي 30 صياد ؛ ينتقلون مع عائلاتهم في موسم الصيد إلى جزيرة صغيرة بالقرب من محطة رفع المياه التابعة لشركة النصر للملاحات ، حيث يعيشون هناك في أكواخ صغيرة مبنية من الأحجار البيضاء ؛ طوال موسم صيد الأسماك ويبيعون صيدهم اليومي الى بعض التجار من مدينة العريش . وكان الصيادون في المحمية يستخدمون حوالي 13 مركب غير حديث وغير مجهز بالمحركات ولكن مشروع صون الاراضى الرطبة استطاع ان يوفر لهم بعض المراكب الحديثة المجهزة بالمحركات.

ويقدر متوسط الانتاج السمكى من البحيرة بحوالى 3000 طن، وقد وصل عام 2005 الى 3534 طن بما يعادل حوالى 7,. % من الانتاج القومى للاسماك فى مصر.ومن اهم انواع الاسماك فى بحيرة البردويل الدنيس والقاروص والموسى الذي يصدر معظمه الى اوروبا .

كما يوجد بعض الحرف اليدوية القديمة مازالت منتشرة بين البدو حتى الان وتساهم فى زيادة دخل الاسرة، مثل صناعة الملابس التقليدية للبدو والصناعات المرتبطة باغصان النخيل وغيرها.

وقد بدأت شركة النصر للملاحات مشروع استغلال ملاحة الزرانيق عام 1982؛ أي قبل إعلان المنطقة كمحمية طبيعية بثلاثة أعوام عام 1985. وقد بدأ التعاون والتنسيق بين الشركة وإدارة المحمية مباشرة بعد إعلان المحمية، وتم تذليل كل العقبات التي كانت تواجه إدارة المحمية من جهة نشاط استخراج الأملاح وتأثيره على بيئات وكائنات المحمية، وقد بدأ الإنتاج الفعلي التجاري للملح عام 1997. والشركة تشغل حوالي 16.5كم2 من مساحة المحمية، ومتوسط كمية المياه التي تسحبها الشركة من مياه البحيرة لاستخلاص الأملاح تقدر بحوالي 250 مليون متر مكعب سنوياً . كما قدرت كمية الأملاح المستخلصة خلال عام 2002/2001 بحوالي 336 آلف طن، صدر حوالي 98 ألف طن خارج مصر، وكان العائد السنوي الكلي للإنتاج حوالي 19.5 مليون جنيه مصري. والأملاح المستخرجة من

ملاحات بحيرة البردويل تعتبر من أنقي وأنظف أنواع الأملاح على المستوي القومي، ولذلك فلا يوجد أي مشاكل في تسويقه سواء في داخل أو خارج مصر.

أما بالنسبة للانشطة السياحية، فان ساحل البحر المتوسط شمال سيناء قد بدأ يعانى من التنمية السياحية التى ادت الى انشاء كثير من المنتجعات غرب وشرق العريش وحتى حدود محمية الزرانيق. هذا ادى الى تدمير كثير من المناطق والبيئات الهامة بما فيها من حياه طبيعية.

وبالاضافة الى الشاطىء الرملى الطويل على الساحل، فانه يوجد عدة اماكن سياحية تاريخية هامة مثل مدن الفلوسيات التى يرجع تاريخها الى العصر الرومانى والكوينات الذى يرجع تاريخها الى العصر الاسلامى، بالاضافة الى بعض الاماكن الاثرية الاخرى الموجودة على الحاجز الرملى بين البحر المتوسط وبحيرة البردويل.

إن أي تغير جوهري في بيئة البحيرة سوف يؤثر تأثيراً كبيراً على التركيب الاجتماعي والعائد الاقتصادي لأفراد المنطقة . لذلك يعتبر مشروعا استصلاح الأراضي في شمال سيناء وترعة السلام في الجنوب من أهم التهديدات التي يمكن أن تؤثر على بحيرة البردويل ومنطقة الزرانيق سلبياً ؛ حيث من المتوقع أن تصل مياه الصرف الزراعية بطريقة أو بأخرى إلى مياه البحيرة، وبالتالي سوف يتغير كثيراً مستوى الملوحة في المياه ويختفي كثير من الأنواع التي تعيش هناك. وأيضا سوف تتلوث المياه الجوفية من مياه الصرف الزراعي المحملة بالمبيدات والمخصبات وتصبح غير صالحة للاستهلاك الآدمي بل ربما تظهر بعض الأمراض التي كانت غير شائعة في شمال سيناء مثل مرض البلهارسيا، عندما تأتي القواقع الناقلة لهذا المرض مع مياه ترعة السلام. كما أن زيادة التجمعات السكانية بعد اتساع الرقعة الزراعية سوف يغير كثيراً في التركيب السكاني ويزيد أيضا كمية الملوثات في المنطقة، وخصوصاً الناتجة من الصرف الصحي. لذلك فان برامج الرصد والحماية بالمنطقة لابد من استمرارها ومتابعتها والتوعية البيئية والتنموية لابد ان تزداد حتى لأصحاب القرار التنفيذى وذلك لكى نضمن عدم تدمير هذه المنطقة الهامة.

15- خطة إدارة بحيرة البردويل ومحمية الزرانيق

تم اختيار محمية الزرانيق ومنطقة البردويل لوضع خطة إدارة لها من قبل مجموعة العمل الوطنية التي تأسست من خلال مشروع صون الأراضي الرطبة والمناطق الساحلية في حوض البحر المتوسط – وذلك لعدة أسباب من أهمها:

أ – أهمية البحيرة والمحمية كموقع فريد لهجرة الطيور علي المستوي العالمي، حيث أنها تمثل أحد الممرات الرئيسية لهجرة الطيور من شرق أوروبا وشمال غرب اسيا إلي افريقيا. لذلك فقد أنضمت المحمية إلي قائمة المحميات الطبيعية التي ترصدها أتفاقية " رامسار " الخاصة بحماية الأراضي الرطبة ذات الأهمية الدولية للطيور المائية. وايضاً أعلنت كمنطقة ذات أهمية عالمية بالنسبة للطيور [**IBA**] وذلك من قبل المنظمة الدولية لحماية الطيور.

ب – تعتبر منطقة البردويل وخاصة الزرانيق من أغني مناطق مصر في تنوعها الحيوي الذي يشمل أكثر من 900نوع معروف حتي الأن، ومنها 5 أنواع متوطنة في مصر. 16نوع مهدد بالأنقراض عالمياً. لذلك فقد أعلنت محمية طبيعية بقرار رئيس مجلس الوزراء رقم 1429 لعام 1985 كمحمية من النوع " معزل طبيعي " في إطار القانون 102 لسنة 1983 في شأن المحميات الطبيعية.

جـ – تعتبر بحيرة البردويل [ومنها بركة الزرانيق] من أهم مصادر الأسماك البحرية بشمال سيناء، وهي حتي الأن البحيرة الساحلية الوحيدة الغير ملوثة، ولذلك ينبغي حمايتها وإدارتها بكفاءة لمنع تلوثها مستقبلاً .

د – وجود بعض المشاكل البيئية والتنموية في المنطقة ومنها:

1- زيادة نسبة صيد الطيور – خاصة السمان – سواء بالطرق المشروعة أو غير المشروعة علي طول ساحل البحيرة.

2- زيادة الصيد الجائر لأصبعيات الأسماك، وأيضاً أستخدام حرف الصيد غير القانونية.

3- الرعي الجائر في كثير من مناطق المحمية وتأثيره المباشر علي التنوع الحيوي، خاصة للطيور والزواحف.

4- زيادة جمع النباتات الخشبية كمصدر للطاقة، وايضاً النباتات الطبية للاتجار بها .

5- إزالة بعض البيئات الطبيعية لزراعة بعض المحاصيل مكانها .

6- زيادة أنشطة وتوسعات شركة النصر للملاحات وتأثيرها علي البيئات الطبيعية وبعض أنواع الكائنات. والحياه البرية عموماً داخل المحمية .

7- زيادة التوسع العمراني ونمو القطاع السياحي بما فيها بناء الفنادق والمنتجعات علي طول ساحل البحر المتوسط مما أدي إلى زيادة الضغط علي محمية الزرانيق والمطالبة ببناء المنتجات ببعض المناطق الساحلية أمام المحمية.

8- التزايد البالغ لعدد السكان ومن ثم تزايد ضغوطهم علي النظم البيئية بالمحمية.

وبعد الدراسات الحقلية التفصيلية عن خصائص ومميزات بحيرة البردويل بما فيها المحمية، وإحتياجاتها، والمشاكل والمعوقات التي تواجهها، تم تقييمها اجتماعيا واقتصاديا و بيئيا من حيث التنوع الحيوى، الندرة، الهشاشة البيئية، والنموذجية. وتم وضع **الأهداف** الأساسية طويلة الأمد في خطة إدارة منطقة البردويل وخاصة محمية الزرانيق، وتشمل:

1- المحافظة علي المميزات البيئية والجمالية للمحمية.

2- المحافظة علي الثروات الطبيعية بالمحمية من خلال الإدارة المستدامة.

3- تحسين الجوانب الاقتصادية والاجتماعية للأفراد المقيمين بالمحمية.

4- رفع مستوي الوعي البيئي بأهمية صون الطبيعة.

5- حل المشاكل القانونية الخاصة بتملك الأراضي بالمحمية.

6- زيادة مساحة المحمية لتشمل بحيرة البردويل بأكملها، وتحويل الزرانيق إلي منطقة ذات حماية خاصة.

ولتحقيق أى هدف أساسي طويل الامد لابد من وضع بعض الأهداف العملية التي يمكن تطبيقها علي المدى القصير، يمكن قياسها ومتابعتها عن طريق برنامج رصدي. ومن أجل إنجاز كل هدف عملي لابد من تحديد بعض المشاريع الصغيرة التي في النهاية تحقق هدفا أو أكثر. وبناءاً على ما سبق تم تحديد الأهداف العملية التالية:

*** المحافظة علي المميزات البيئية والجمالية للمحمية**

1- تحديد مناطق حماية تتابين إجراءات إدارتها.

2- إنشاء متحف مرجعي بالمحمية .

3- إنشاء عيادة طبية للحيوانات البرية

4- وضع برنامج حقلي لصون الأنواع

5- وضع نظام لإدارة المعلومات

6- وضع برنامج بحثي حقلي

7- تصميم برنامج رصدي للتغيرات البيئية

*** المحافظة علي الثروات الطبيعية بالمحمية من خلال الإدارة المستدامة**

1- العمل علي تنمية الثروة السمكية

2- تفعيل تنفيذ القانون

*** تحسين الجوانب الاقتصادية والاجتماعية للأفراد المقيمين بالمحمية**

1- بناء ورفع القدرات للأفراد في شتي المجالات

2- تنمية السياحة البيئية

3- رفع القدرة علي زيادة التمويل المالي

4- تنمية مصادر الدخل البديلة

*** رفع مستوي الوعي البيئي بأهمية صون الطبيعة**

1- رفع مستوي الوعي العام

2- وضع برامج الإعلام

3- العمل علي تشغيل الأفراد المقيمين بالمنطقة في إدارة المحمية

*** زيادة مساحة المحمية لتشمل بحيرة البردويل بأكملها، وتحويل الزرانيق إلي منطقة مغلقة ذات حماية خاصة**

1- وضع برنامج لبعض الدراسات الحقلية لبحيرة البردويل والمناطق المحيطة بها مباشرة.

2- اتخاذ الخطوات والإجراءات القانونية لإعلان بحيرة البردويل والمناطق المحيطة بها محمية طبيعية.

وبعد تحديد الأهداف العملية كانت الخطوة التالية هى وضع المشاريع التي تحقق هذه الأهداف والطرائق المختلفة الملائمة لتنفيذها. وتم تقسيم المحمية إلي مناطق مختلفة تساعد كثيراً في حماية المناطق الحساسة الهامة، وفي وضع القواعد والقوانين المنظمة للأنشطة داخل هذه المناطق، وأيضا تساعد مسئولي المحمية عند التطبيق الواقعي لخطة الإدارة. وعموماً يمكن اعتبار محمية الزرانيق في وضعها الحالي وحدة إيكولوجية واحدة؛ ساحلية ذات ملوحة عالية تحتوي على عديد من البيئات الطبيعية مثل الكثبان الرملية والسبخات الملحية والمياه

المفتوحة الضحلة. أما في حالة زيادة مساحة المحمية – كما تقترح خطة الإدارة – فإن المحمية يمكن تقسيمها إلي ثلاث وحدات إيكولوجية ؛ مياه البحيرة ، والسبخات الملحية ، والحاجز الرملي مع فتحات البواغيز الطبيعية والصناعية . وكل من هذه الوحدات الثلاث سوف تتطلب مستوى مختلف من الحماية داخل إطار خطة إدارة المحمية. وفي هذه الحالة سوف تتحول منطقة الزرانيق كلها إلي منطقة قلب ذات ادارة خاصة، أما المناطق الأخرى فسوف تعامل كمناطق حاجزة أو انتقالية.

وقد تم تشكيل لجنة لإدارة المحمية برئاسة محافظ شمال سيناء (الإقليم الذى تنتمى اليه بحيرة البردويل والزرانيق) وعضوية ممثلين من جميع الوزارات والهيئات المتواجدة بمنطقة شمال سيناء وذلك لمتابعة تطبيق مشاريع خطة ادارة المحمية.